https://ntrs.nasa.gov/search.jsp?R=20080015864 2019-08-30T04:26:44+00:00Z

MSFC-205_ABSTRACT

ABSTRACT OF PRESENTATION

TITLE: Welding Development at Marshall Space Flight Center

This paper presents the basic understanding of the friction stir welding process. It covers process description, pin tool operation and materials, metal flow theory, mechanical properties, and materials welded using the process. It also discusses the thermal stir welding process and the differences between thermal stir and friction stir welding. MSFC weld tools used for development are also presented.

MSFC-205_PRESENTATION

WELDING DEVELOPMENT

MARSHALL SPACE FLIGHT CENTER

Jeff Ding

Metallic Materials & Processing

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AGENDA

- Introduction
- Conventional FSW Process:
  - Description
  - Microstructure
  - Hardness
  - Mechanical Properties
- Self Reacting FSW

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Friction Stir Welding and Processing
Ed. R.S. Mishra and M.W. Mahoney
2007, ASM International

1. Introduction (R. Mishra-UMR & M. Mahoney-Rockwell Scientific Co.)
2. FSW Tooling (C. Fuller- Rockwell Scientific Co.)
3. Metal Flow and Temperature Distribution (J. Schneider-MSU)
4. Microstructural Evolution in Al Alloys (A. Reynolds-USC)
5. Mechanical Properties of FSWed Al. Alloys (M. Mahoney-Rockwell Scientific Co.)
6. FSWing of Ferrous and Nickel Alloys (C. Sorensen & T. Nelson-BYU)
7. Microstructure & Mechanical Prop. of FSW Ti Alloys (T. Lienert-LANL)
8. Microstructures & Mechanical Prop. of Cu Alloys (T. McNelley-NPS)
9. Corrosion Properties of FSW Al. Alloys (J. Lumsden - Rockwell Scientific Co.)
10. Process Modeling (A.Askari & S. Silling-Cambridge)
11. Robots & Machines for FSW/FSP (C. Smith-Friction Stir Link, Inc.)
12. Friction Stir Spot Welding (H. Badarinarayan, F. Hunt, K. Okamoto - Hitachi)
13. Application of FSW & Related Applications (W. Arbegast-SDSMM)
14. Friction Stir Processing (R. Mishra-UMR & M. Mahoney-Rockwell Scientific Co.)
15. Future Outlook for FSW/FSP (R. Mishra-UMR & M. Mahoney-Rockwell Scientific Co.)

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Background
Friction Stir Welding

- Jeff Ding brought FSW to the NASA agency in 1995.
- Patented by The Weld Institute (TWI) Cambridge, U.K in 1991.
- Solid state (non-melting) joining process using frictional heat to raise temperature into the metals plastic state.
- Recognized as significant advancements in welding technology.

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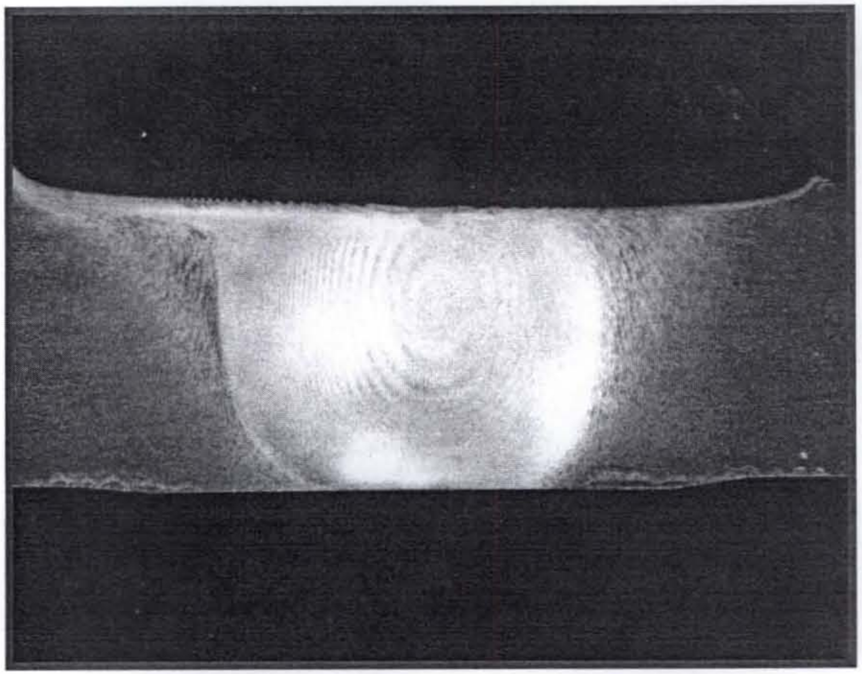
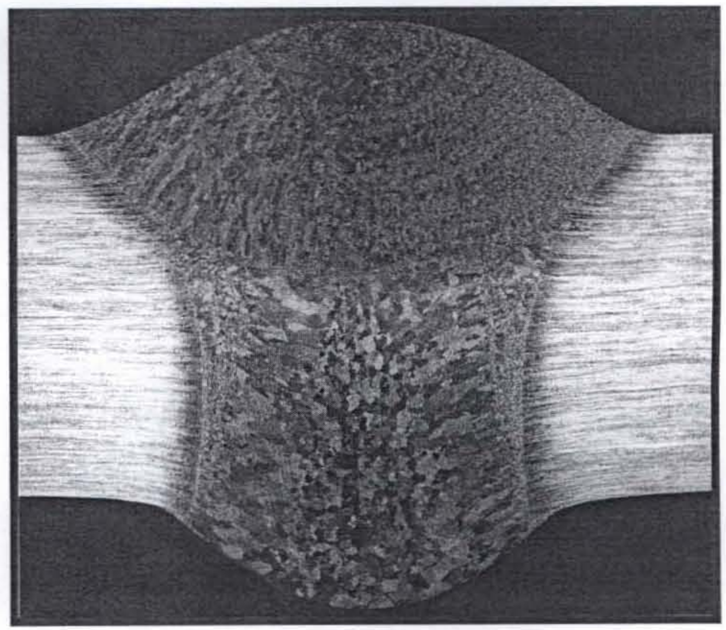
FSW Metallography



Macro transverse section of FSW



Macro transverse section of VPPA

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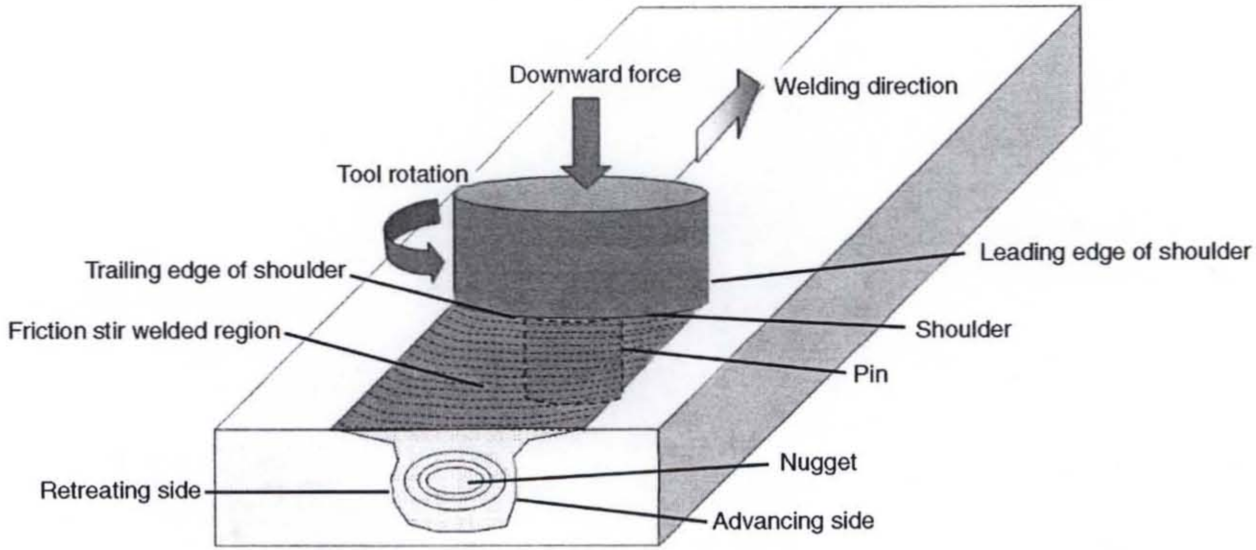
Conventional FSW Process



Chapter 1: Introduction

- **Tool serves 3 primary functions:**
  - **Heat: Heating of workpiece**
  - **Stir: Movement of material to product the joint**
  - **Forge: Containment of material**

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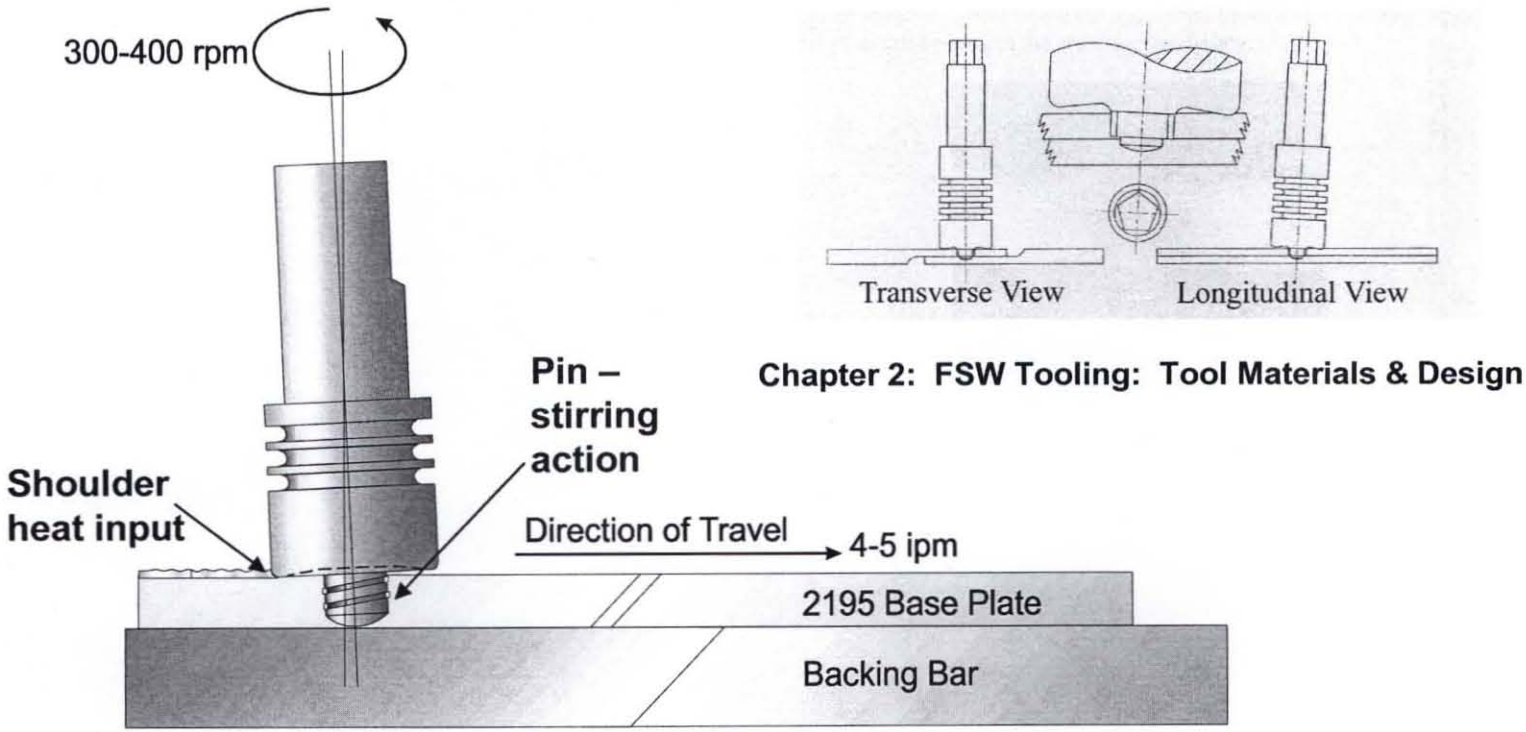
Conventional FSW

Process Parameters



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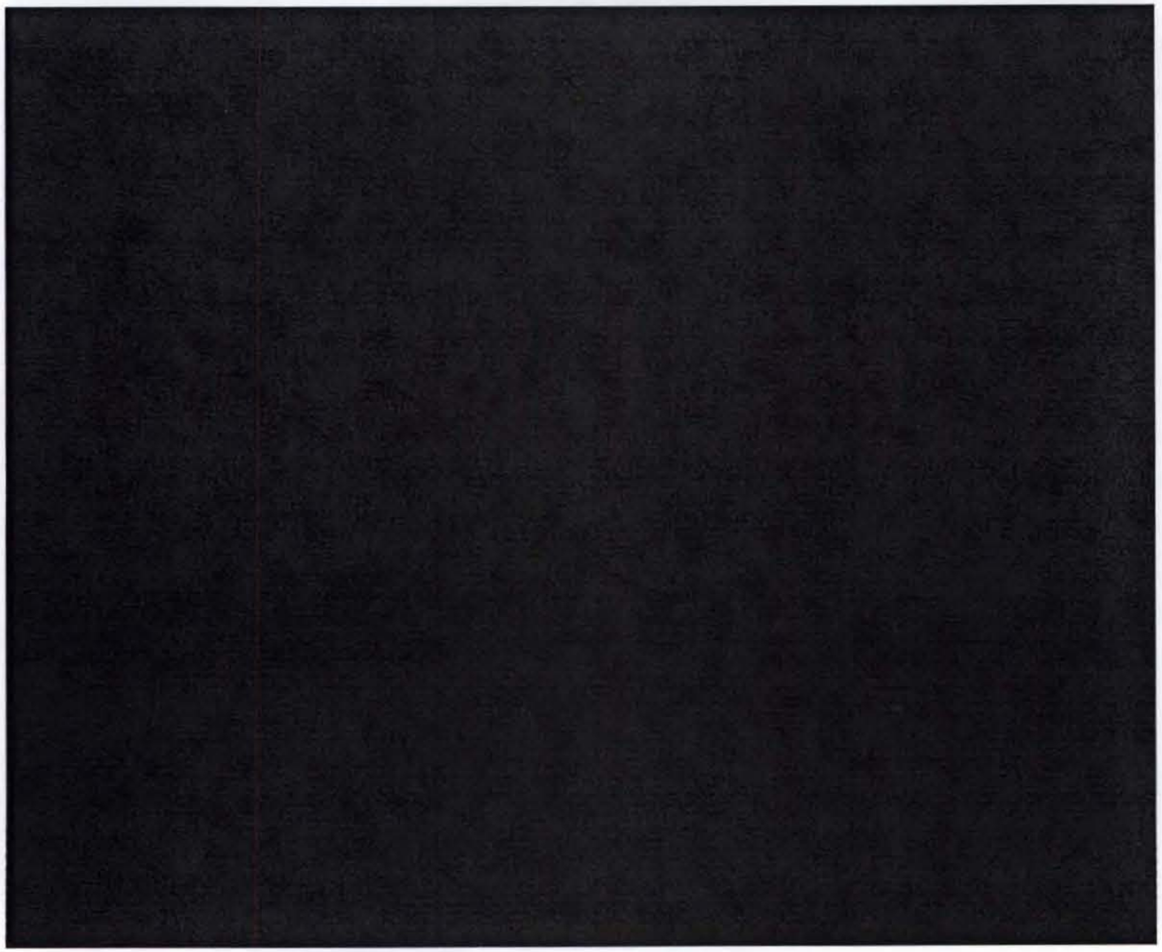
FSW of 1” thick panels



AVI file. Click to Run Movie.

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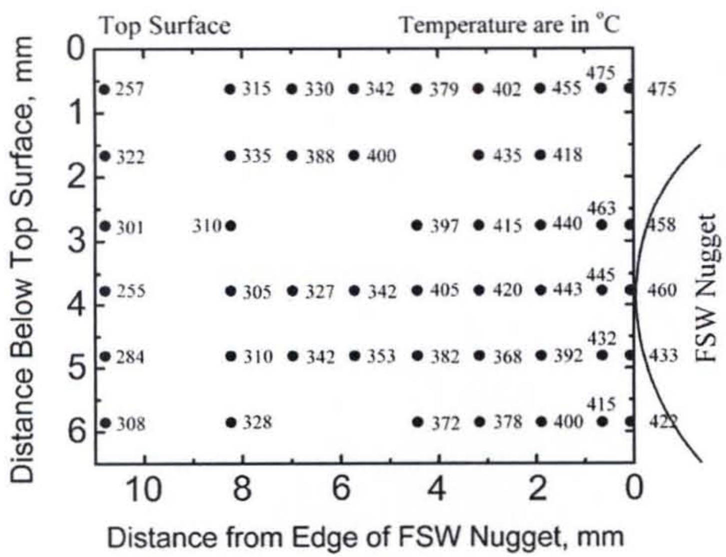
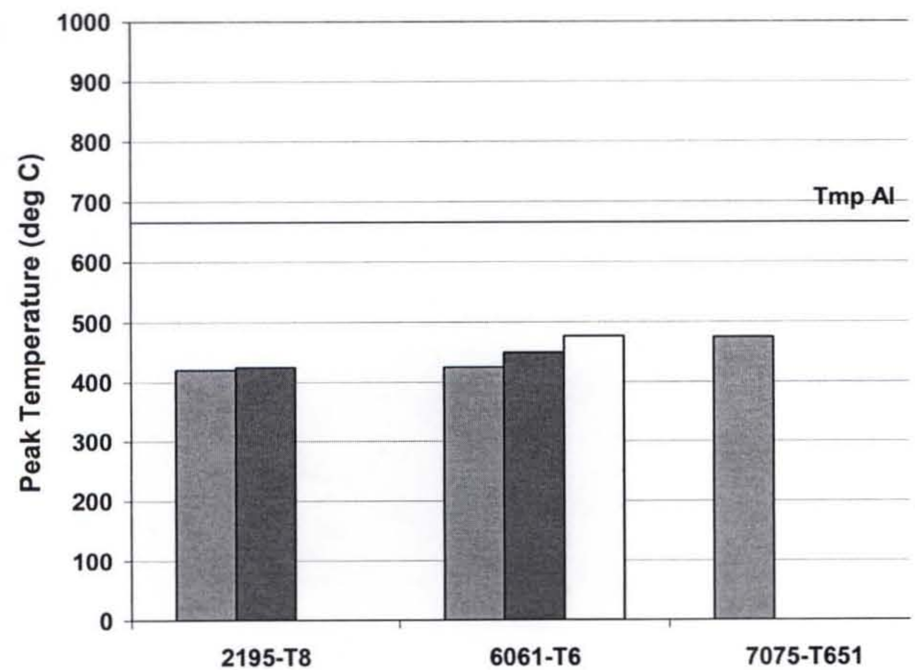
Temperature Distribution in FSW





Chapter 3: Temperature Distribution and Resulting Metal Flow

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June 27, 2007

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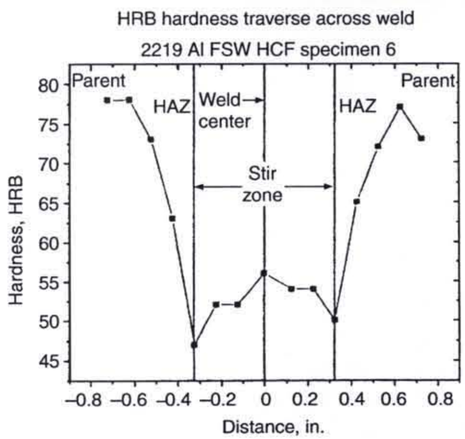
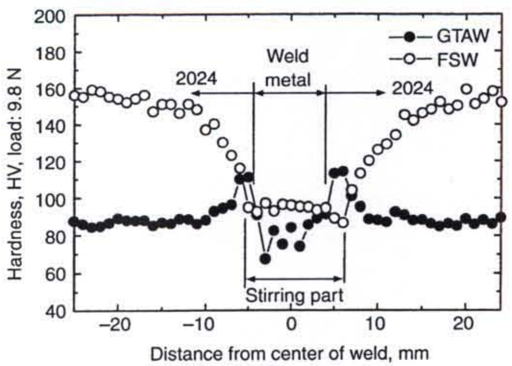
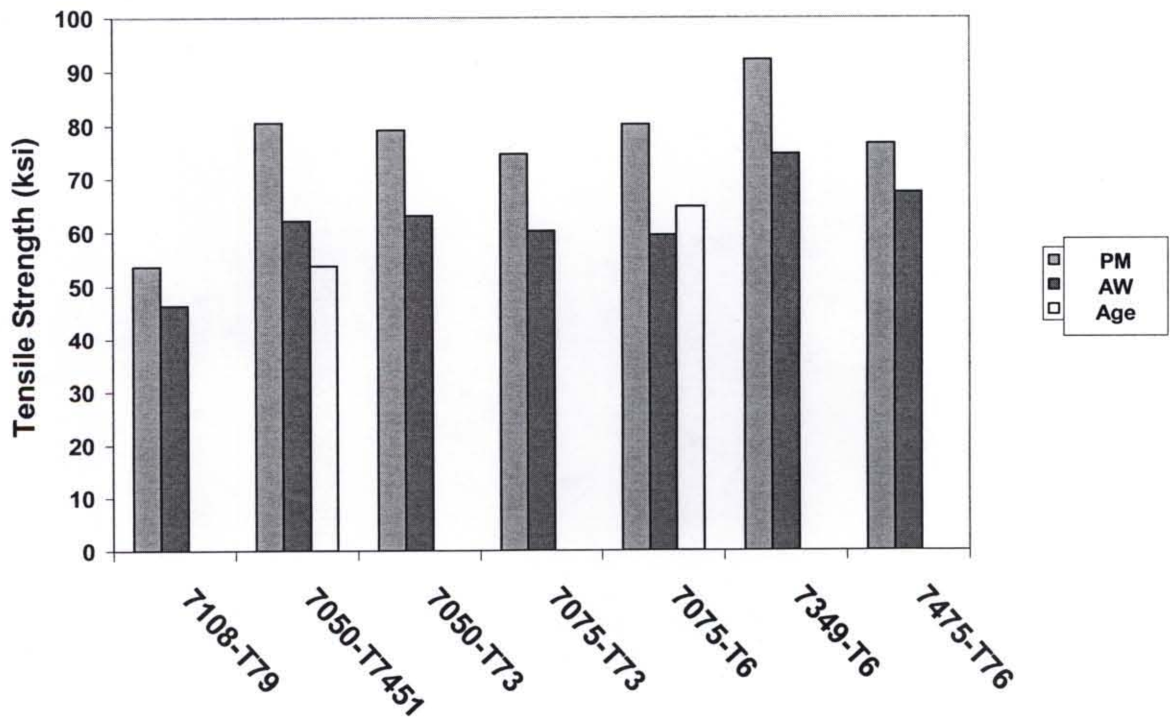
Mechanical Properties



Hardness AA2219



TIG vs FSW Hardness



FSW properties independent of material thickness

	Yield Strength		Tensile Strength		Thickness	
[illegible]	(MPa)	ksi	(MPa)	ksi	(mm)	in
[illegible]	570	82.7	600	87.0	8.1	[illegible]
[illegible]	225	32.6	390	56.6	4	[illegible]
[illegible]	270	39.2	[illegible]	59.5	8.1	[illegible]
FSW	251	36.4	[illegible]	58.2		
[illegible]	249	36.1	[illegible]	57.9	8.1	[illegible]
[illegible]	209	30.3	[illegible]	51.8	16.5	
FSW	217	31.5	[illegible]	53.4	25.4	

FSW Benefits

[illegible]	[illegible]	[illegible]
• Solid phase process • Low distortion • Good dimensional stability and repeatability • No loss of alloying elements • Excellent mechanical properties in the joint area • Fine recrystallized microstructure • Absence of solidification cracking • Replace multiple parts joined by fasteners • Weld all aluminum alloys • Post-FSW formability	• No shielding gas required • Minimal surface cleaning required • Eliminate grinding wastes • Eliminate solvents required for degreasing • Consumable materials saving, such as rugs, wire or any other gases • No harmful emissions	• Improved materials use (e.g., joining different thickness) allows reduction in weight • Only 2.5% of the energy needed for a laser weld • Decreased fuel consumption in light weight aircraft, automotive and ship applications

FSW Limitations

- Exit hole left after withdrawing tool.
- Significant down force and traversing forces required.
- Lacks the flexibility of manual and arc processes.

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Production Benefits Obtained with FSW

- The formation of low distortion, solid-phase, welds of repeatable high quality and mechanical properties, which could improve existing products and lead to a substantial number of new product design opportunities, hitherto not possible, in many different industries.
- Low welding operation costs due to the low welding power requirement and the elimination of filler wires, weld pool shielding gases and the special joint edge preparations required by fusion welding techniques.
- The machine tool operation, once correctly set, does not require operator skill and the machine settings can be easily monitored to provide in-process weld quality assurance.
- The process is clean and does not produce any major safety hazards, such as welding fume or radiation.

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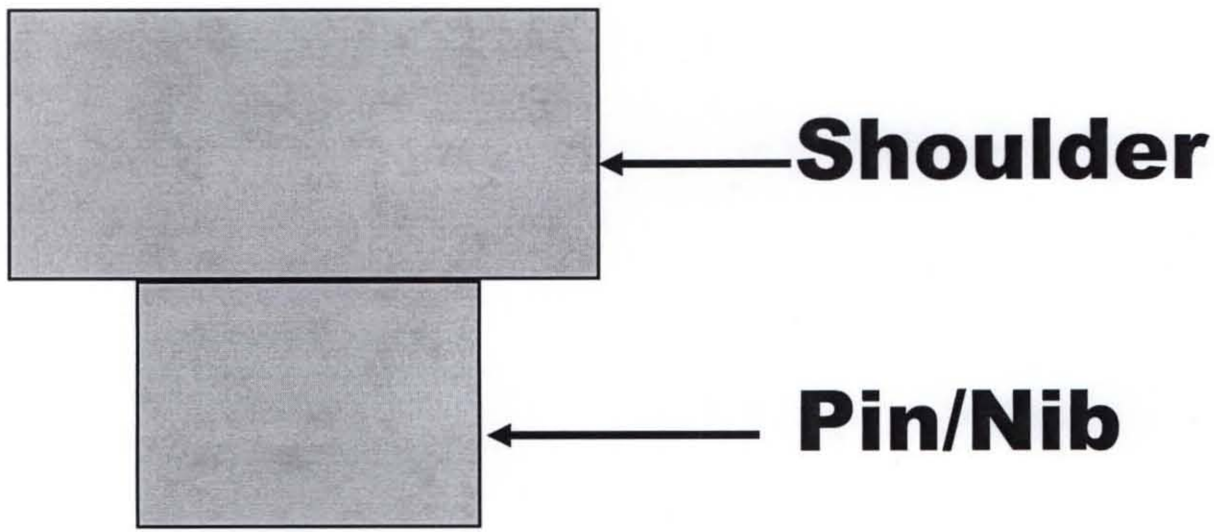
Two basic components of weld tool



Generally the shoulder is twice as wide as the pin.

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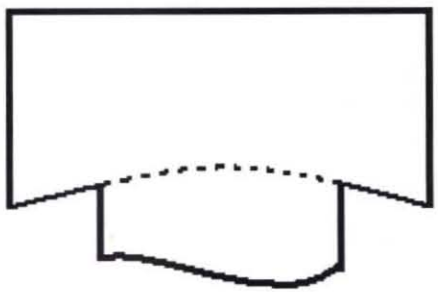
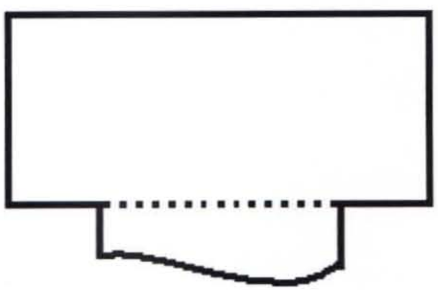
Basic shoulder geometries

Cross sections of pin tool

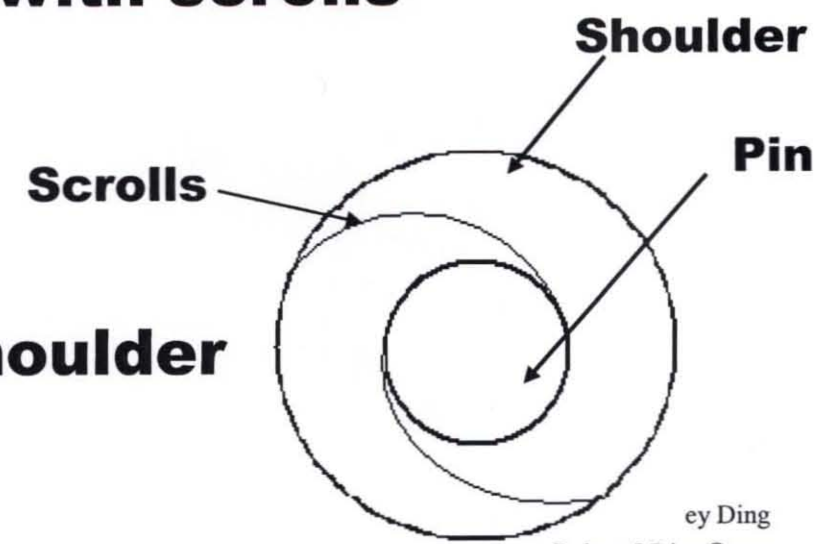


Concave smooth shoulder



Flat shoulder with scrolls

View showing scrolls on shoulder



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Weld Tool Pin Configurations

Threaded features on either cylindrical or tapered pin

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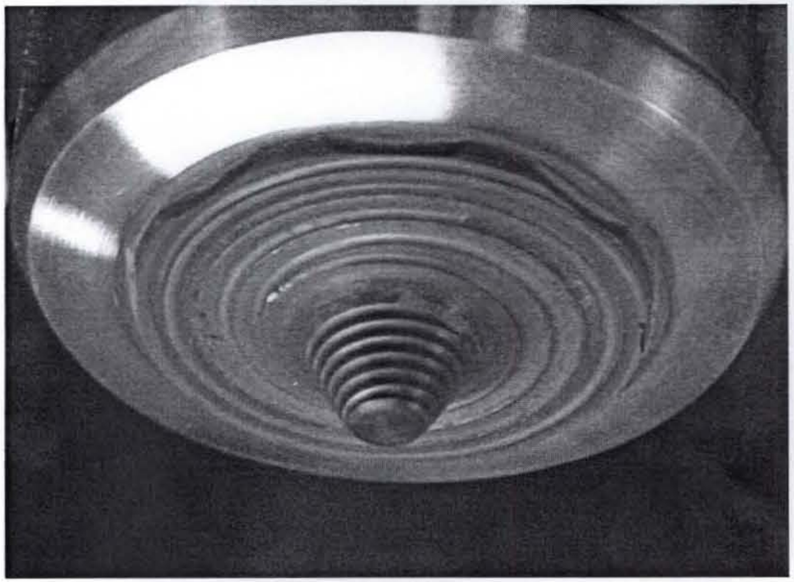
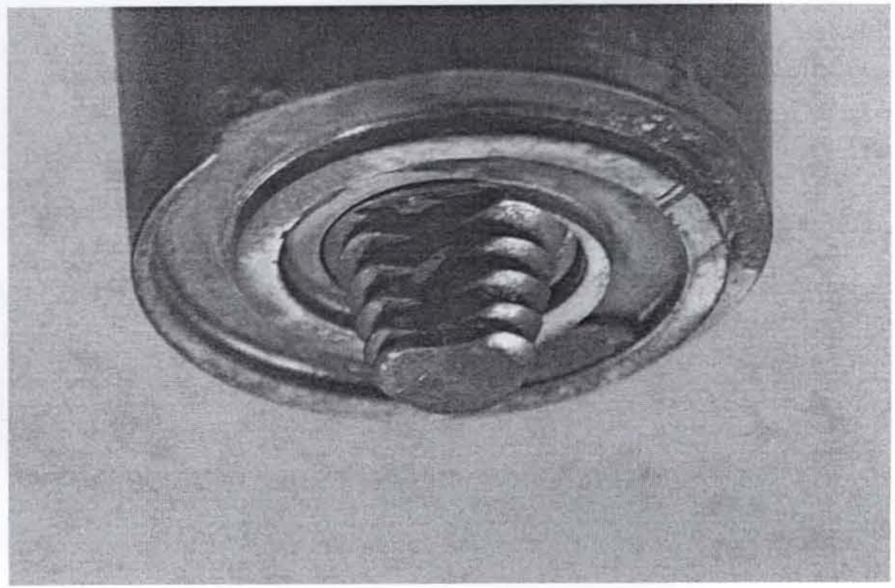
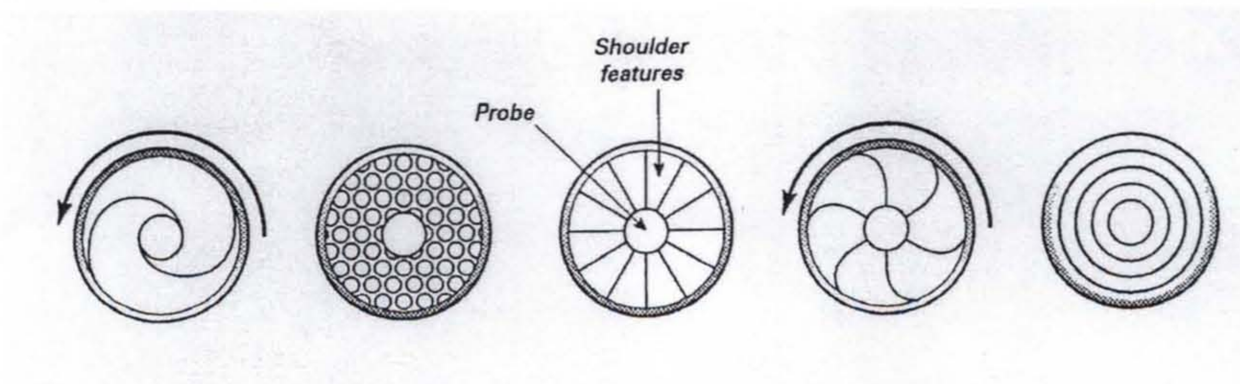
Weld Tool Shoulder Features







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Theorized Metal Flow Paths in FSW

Workpiece/Pin Tool Interaction

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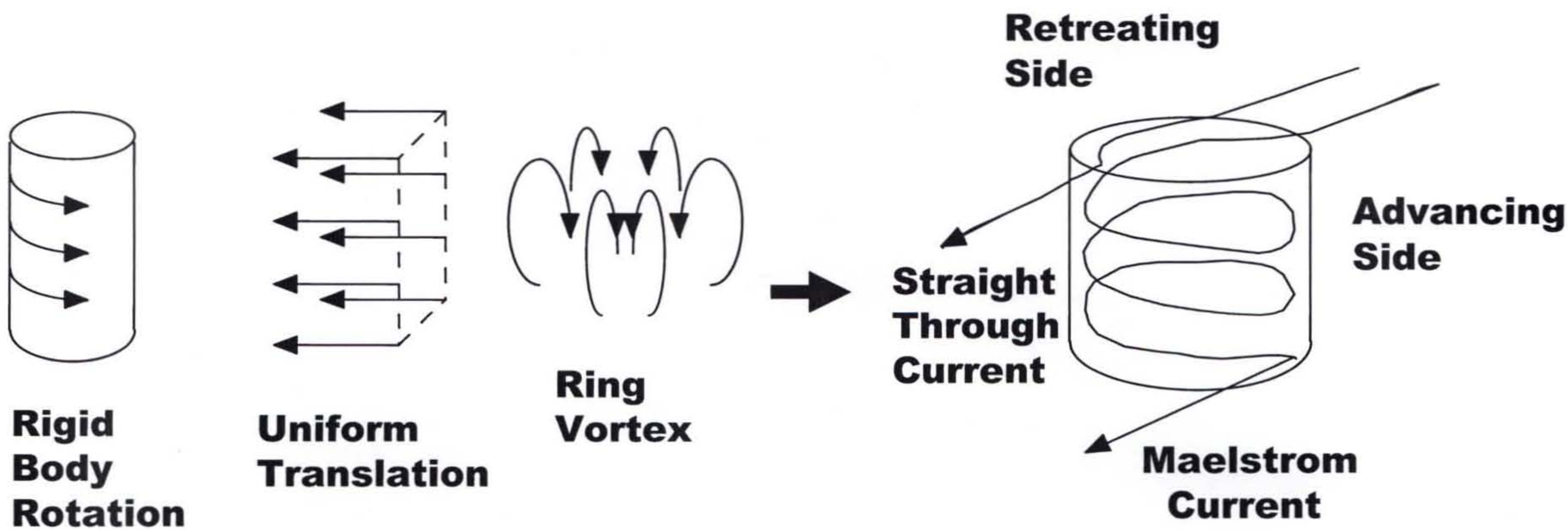
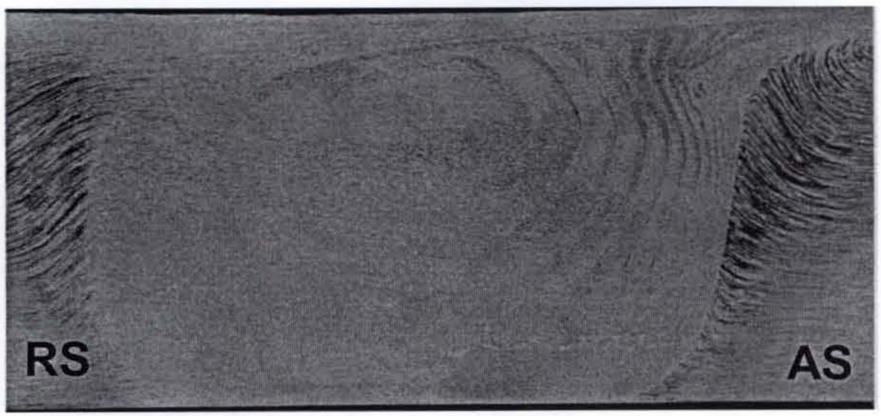
Kinematic mathematical model approach defines the theoretical flow fields and resultant currents in the neighborhood of the conventional FSW tool



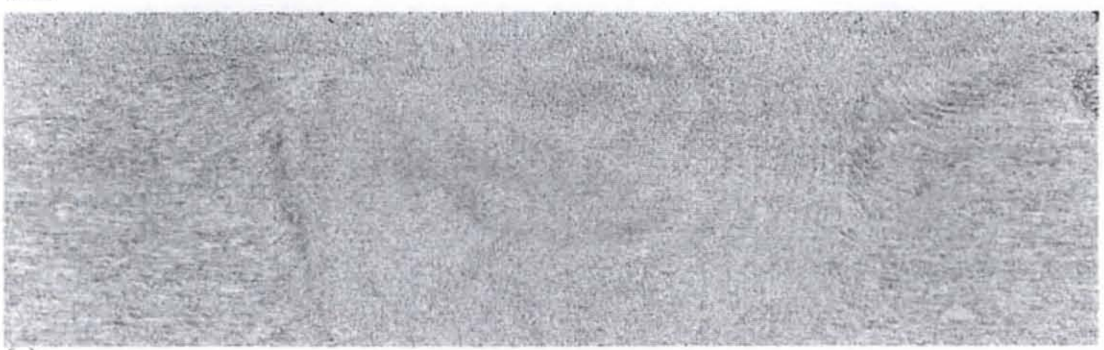
Three incompressible flow fields → two resultant currents

Shear texture bands are observed in the weld nugget

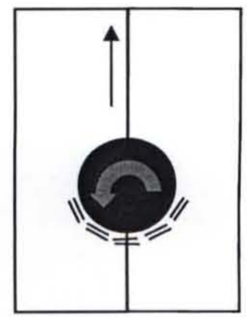
Similar texture has been reported in weld nuggets, independent of the initial PM texture



1000 mm



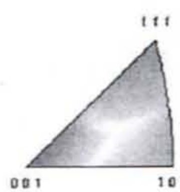
(6063) DP Field, et. al., 2001.
(1100) K.V., Jata, S.L. Semiatin, 2000.



'A' fiber texture

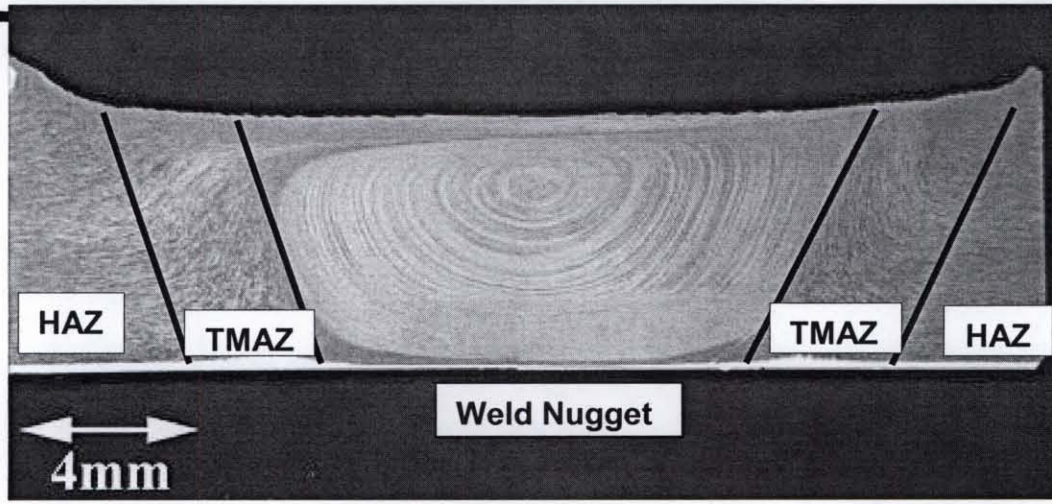
{111} <hkl>

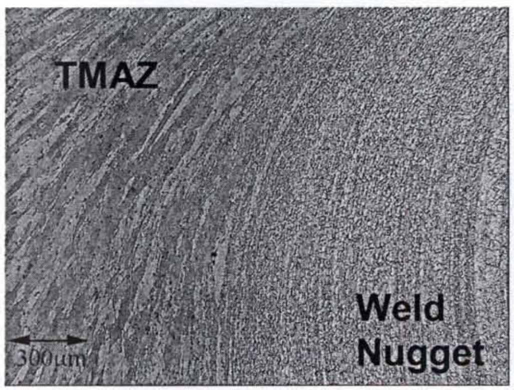
2195-T8



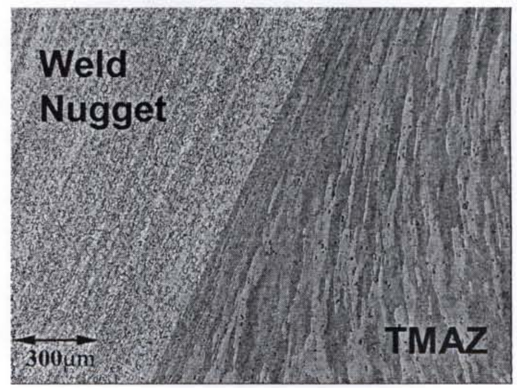
Schneider, J.A., Nunes, Jr., A.C., *Met. Trans. B*, 2004.

FSW Microstructure





Retreating side



Advancing side.

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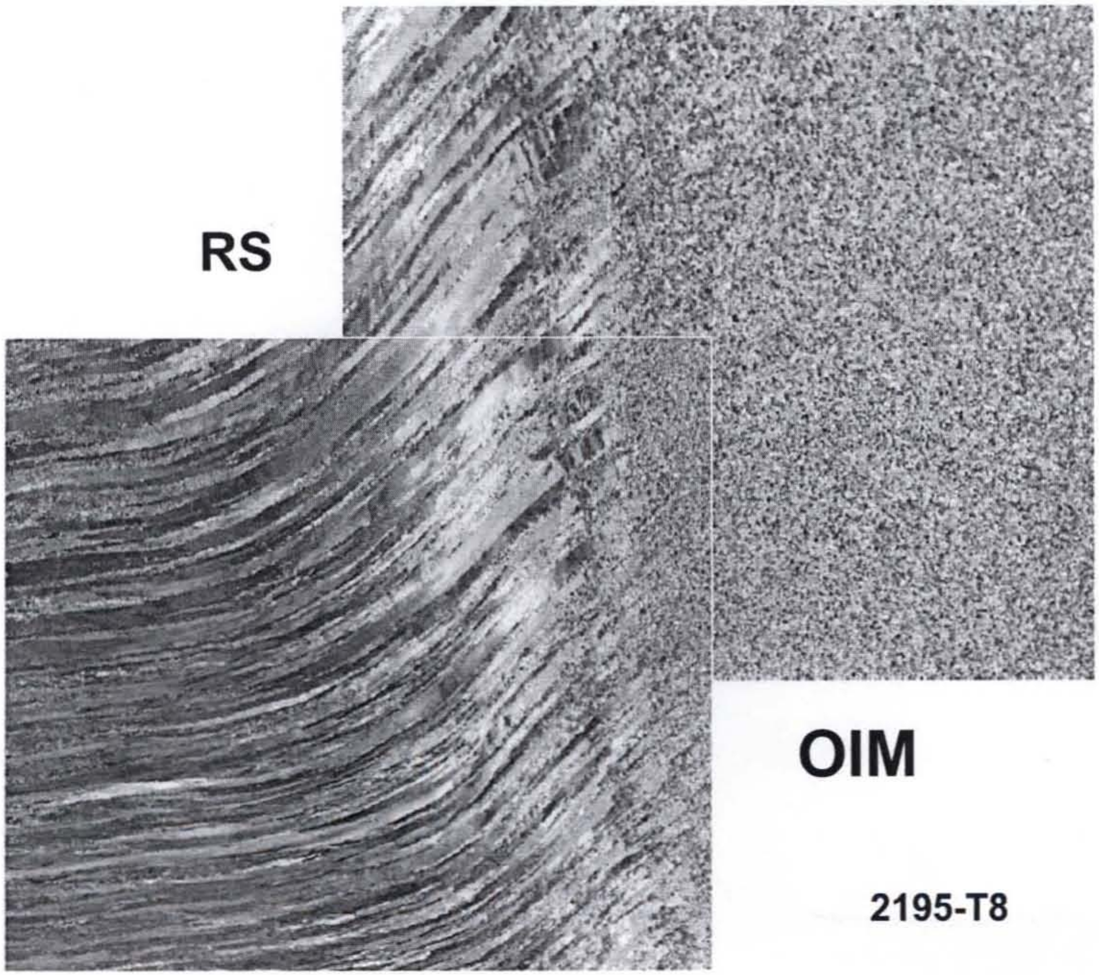
Sharp boundary exists between parent grains and recrystallized nugget grains

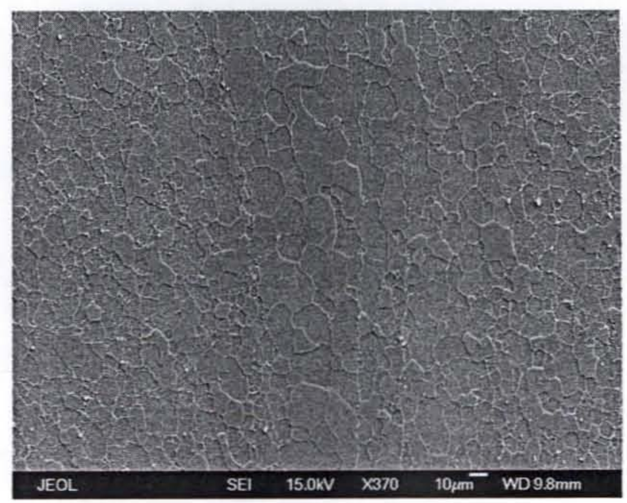
RS



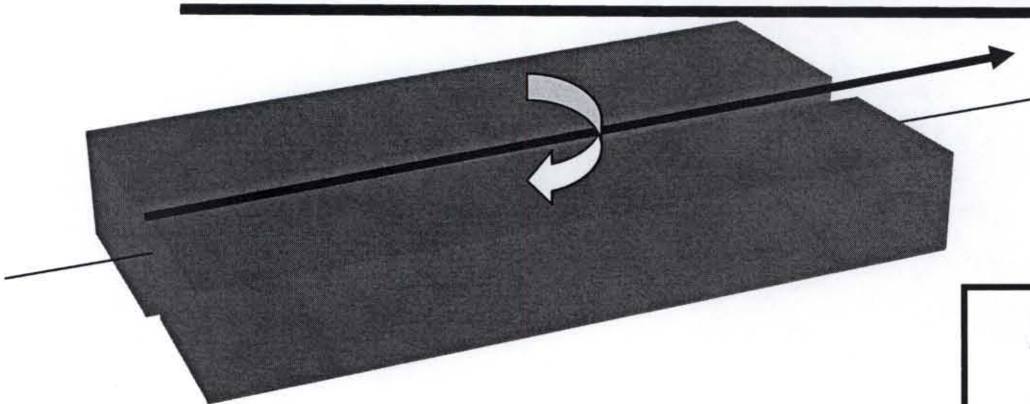
OIM

2195-T8

Optical light Micrograph of weld nugget



Studies were conducted to trace variations in the metal flow paths



Based on position and process parameter

Force (lbf)	Travel (ipm)	Rotation (rpm)
6500	3	150
7000	4.5	200
8000	6	300

Study produced:
117 each 6.5 " welds

- Tungsten wire: 0.001" dia
- Al 2219 plates: 0.25" thick

Colligan, Welding Journal, 1999.

Seidel & Reynolds, Met. & Mat. Trans. A, 2001.

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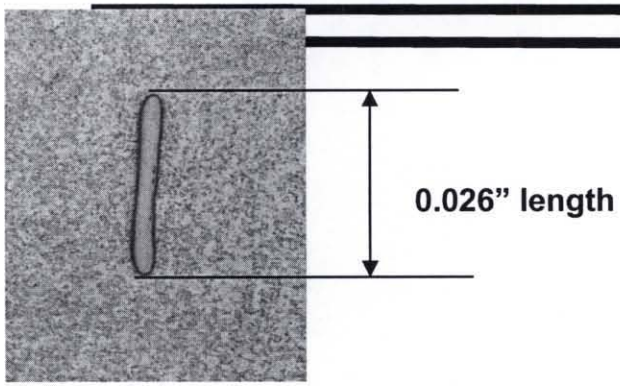
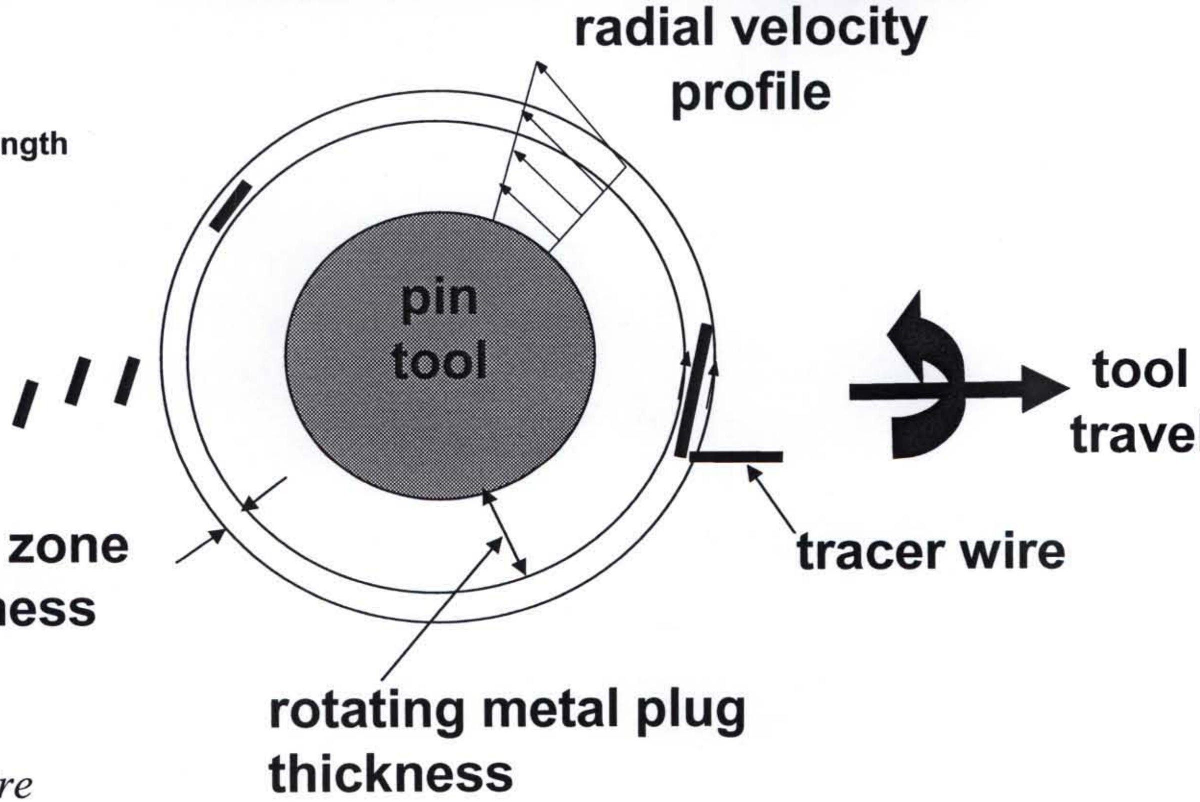
Strain experienced by the metal can be determined from a wire marker spacing



Optical image

Initial dia. = 0.0025”
Final dia. = 0.0024”



$$\Delta L \approx r \frac{\sigma_{tungsten\_wire}}{\sigma_{weld\_metal}}$$

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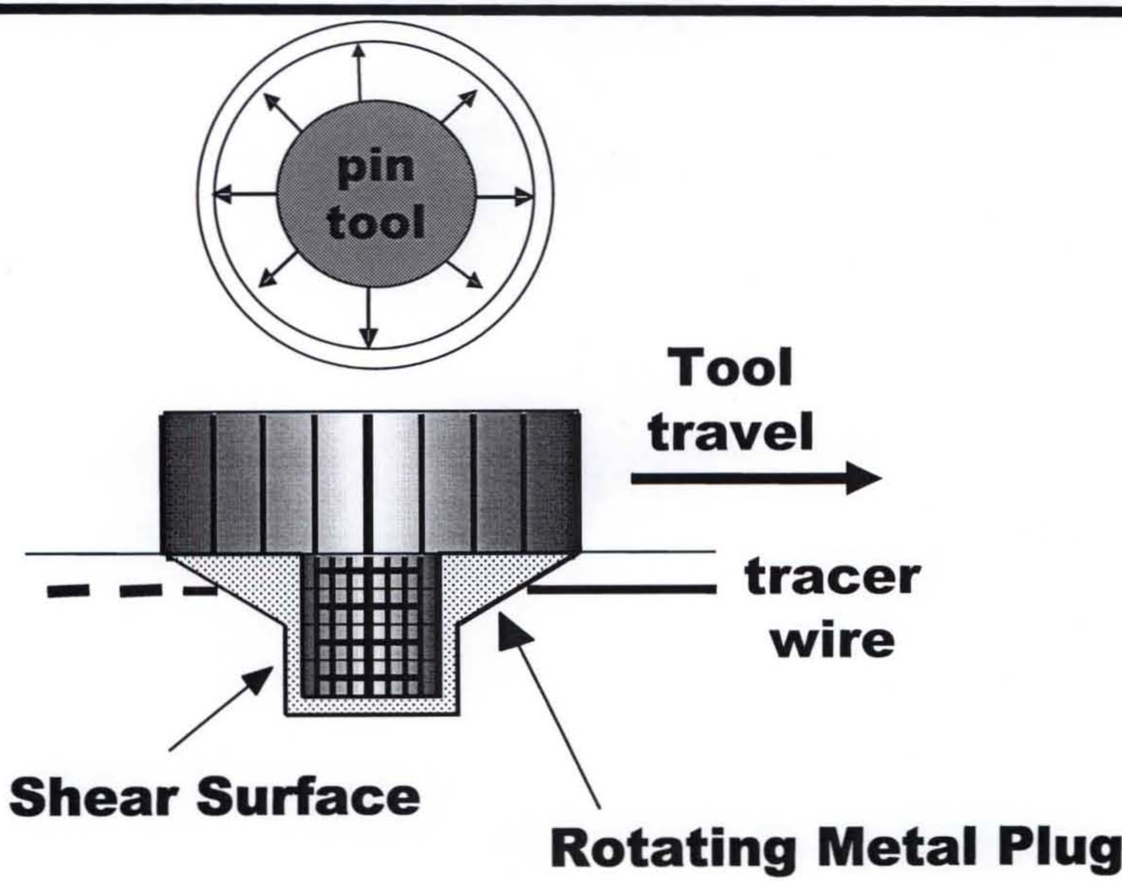
The rotating plug of metal contains the Maelstrom current



Nunes, Automotive Alloys and Joining Aluminum, TMS, 2001.

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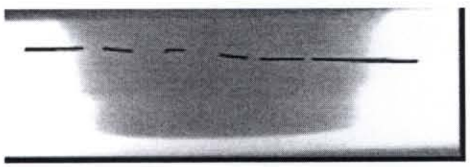
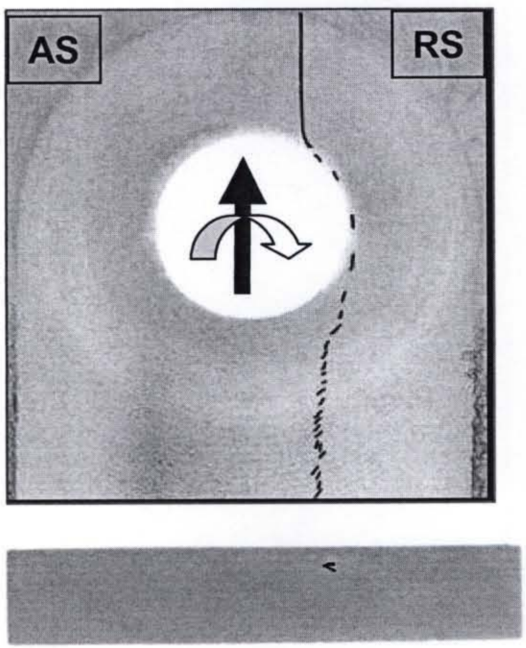
Summary of metal flow variation with entrance into weld zone



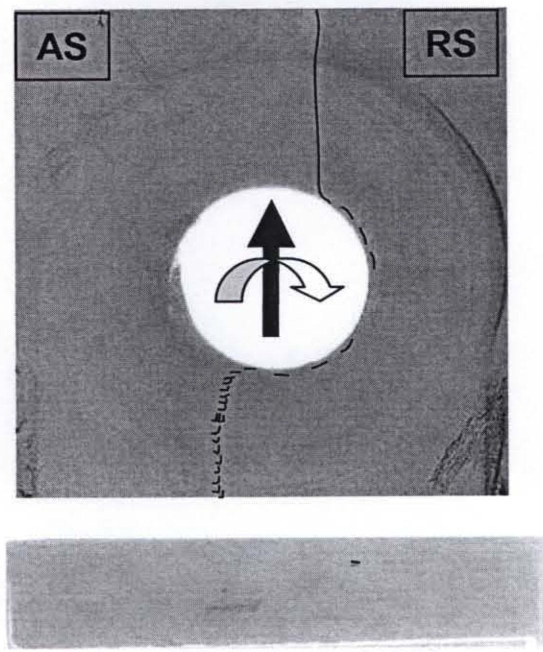
C05

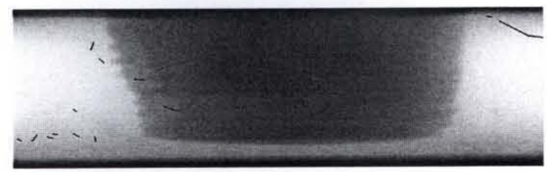
8000 lbf /200 RPM /4.5 ipm



C20

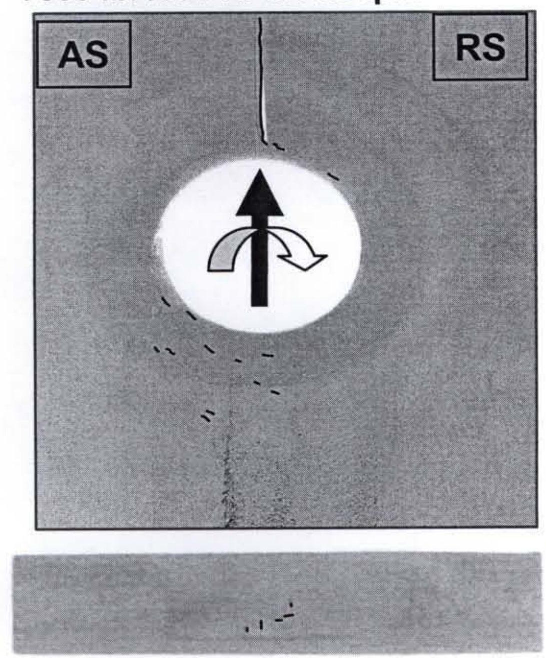
7000 lbf /300 RPM /4.5 ipm





C22

7000 lbf /300 RPM /4.5 ipm



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Self Reacting Friction Stir Welding
(SR-FSW)

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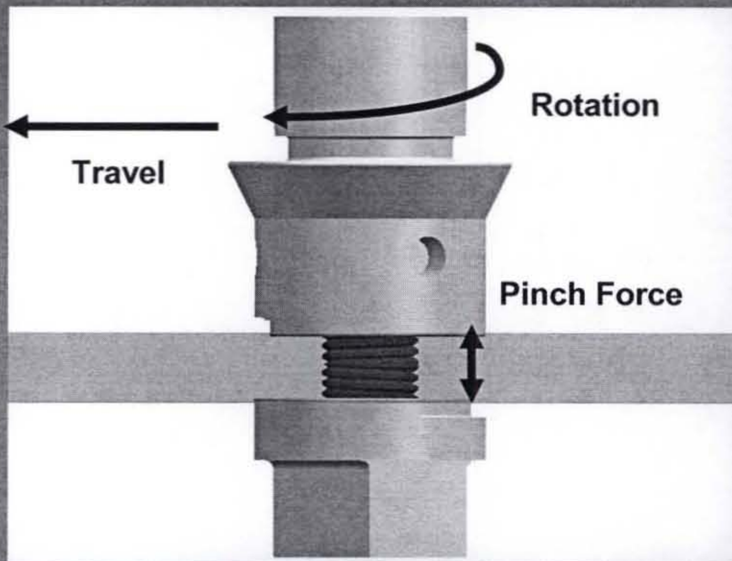
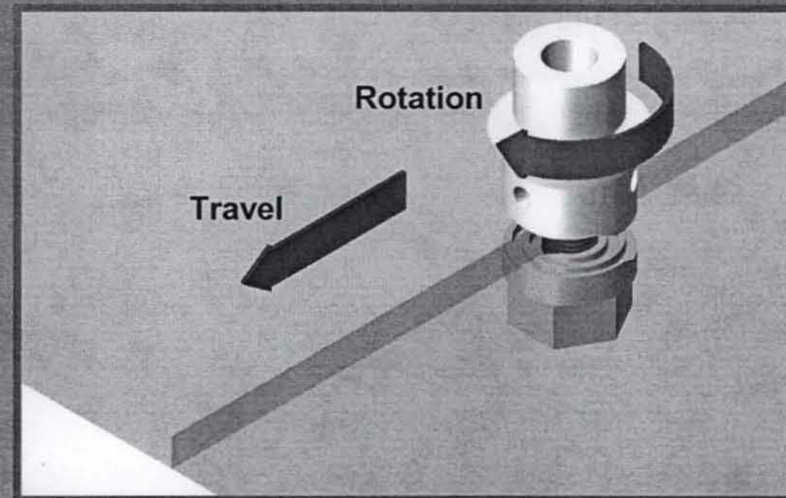
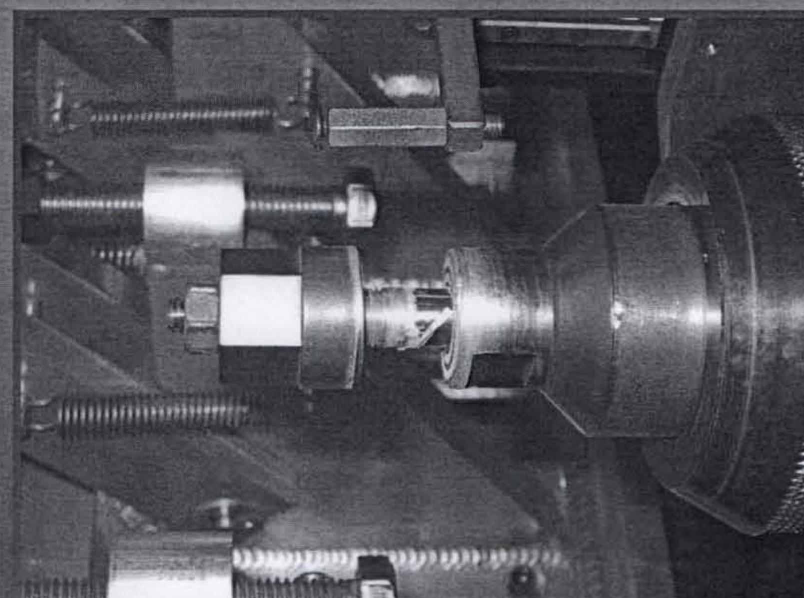
SR-FSW
2001- PRESENT



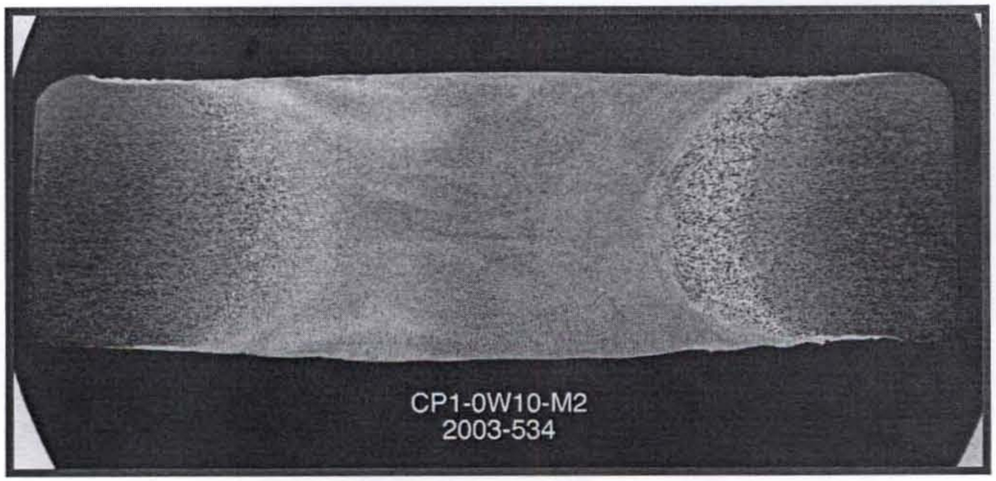




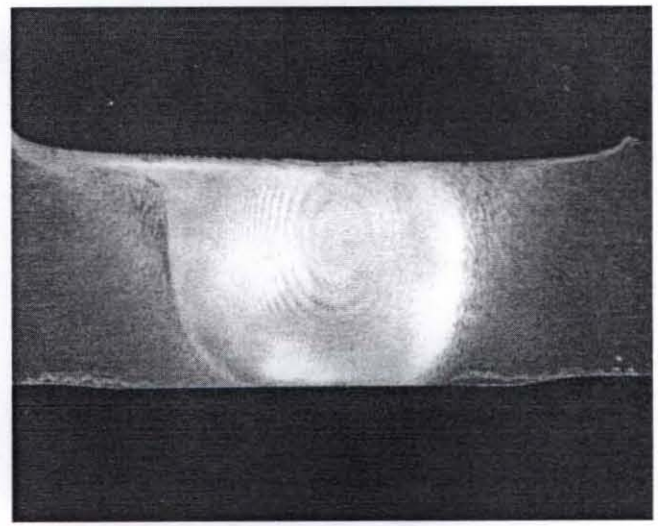
Purpose of Development:
- Natural/Logical evolutionary step.
- Goal is implementation on External Tank and other Large-Scale Aluminum cryogenic tanks.

Advantages over Conventional FSW:
- No Anvil Required – Simplified Tooling.
- Lowers Potential for Creating Defects (LOP).
- Faster Travel Rates.

Similar Macro Transverse Sections in SR-FSW and C-FSW



Macro transverse section of SR-FSW



Macro transverse section of FSW

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FSW Weld Tools

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June 27, 2007

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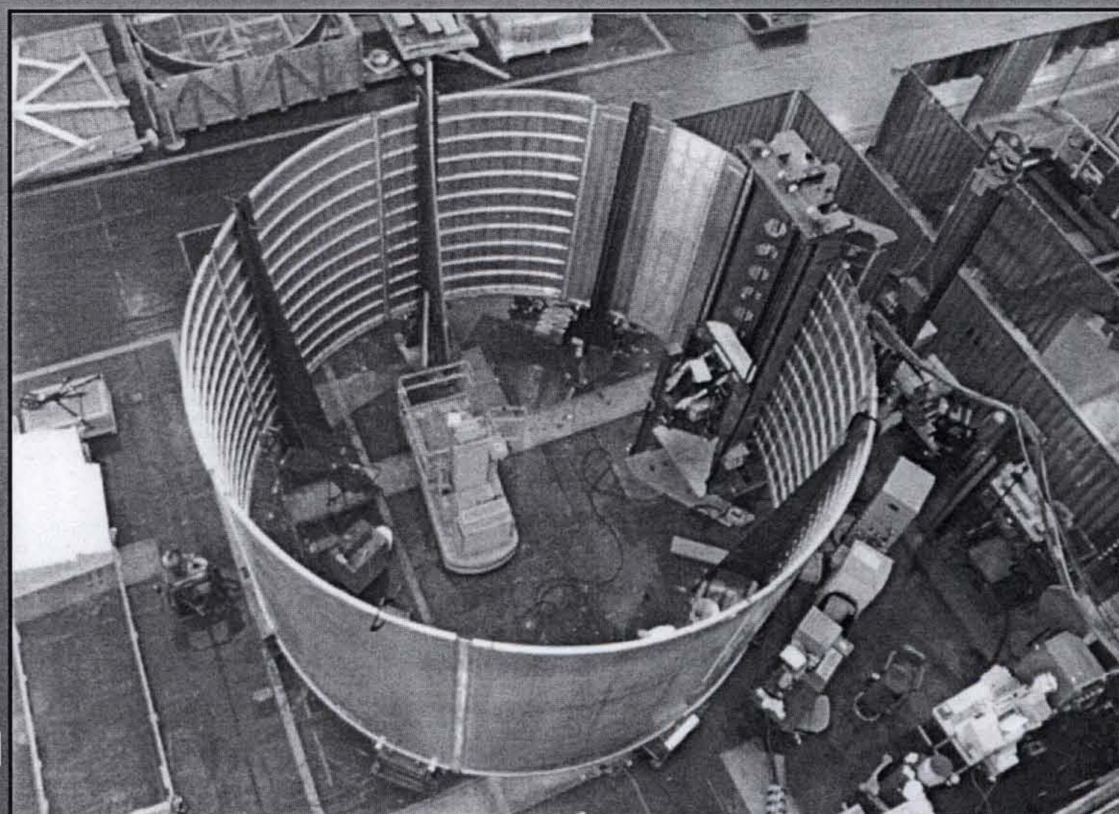
Conventional FSW Development

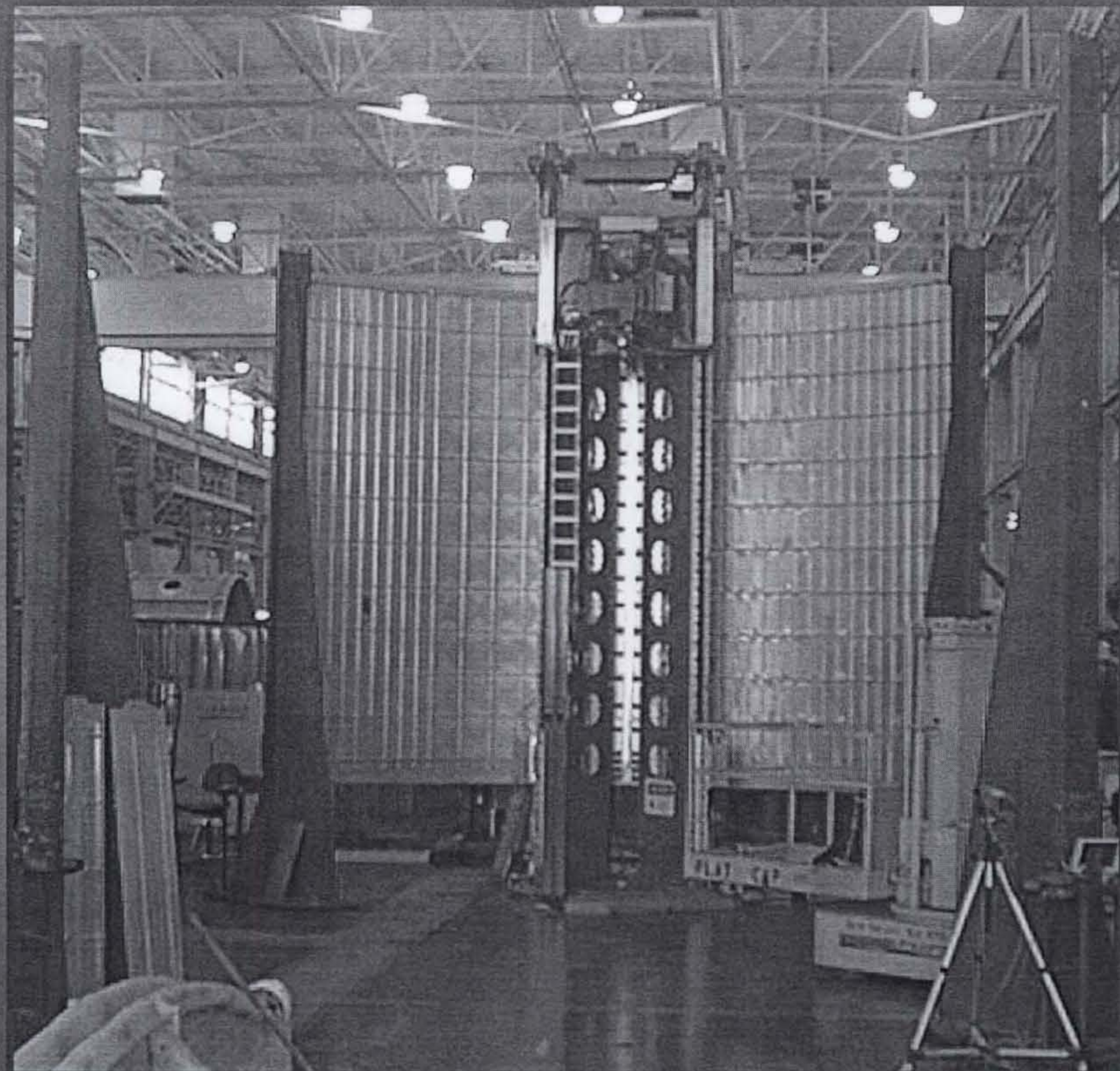
Panel Welding Development

↓

27.5' ET Hydrogen Barrel #1
Demonstration
at MSFC

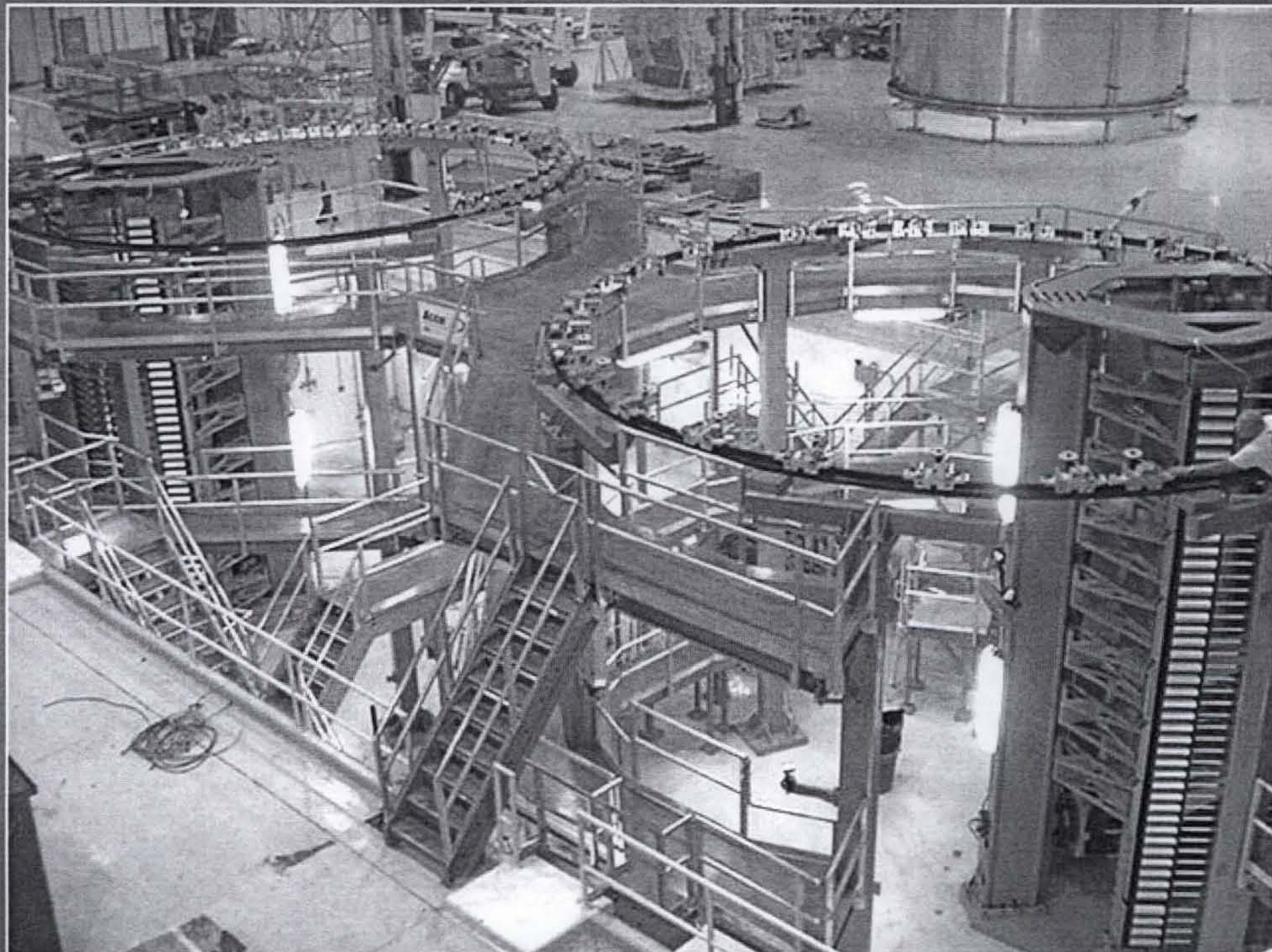


Vertical Weld Tool
Bldg. 4705



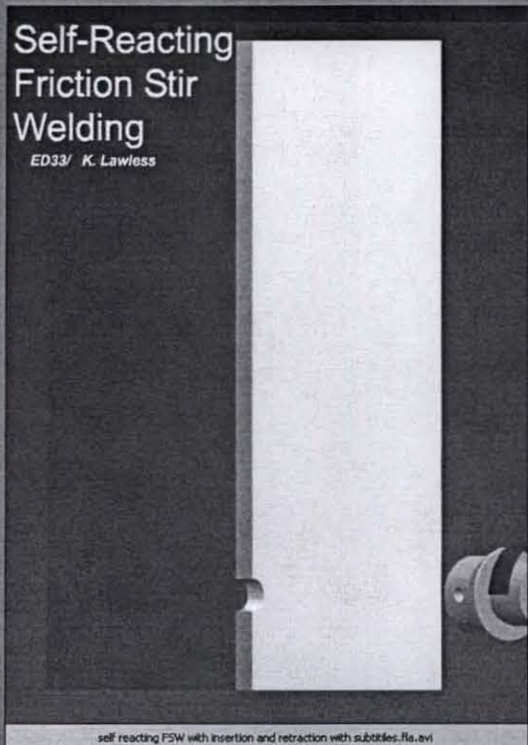
NASA-MSFC Vertical Weld Tool

External Tank FSW Barrel Implementation

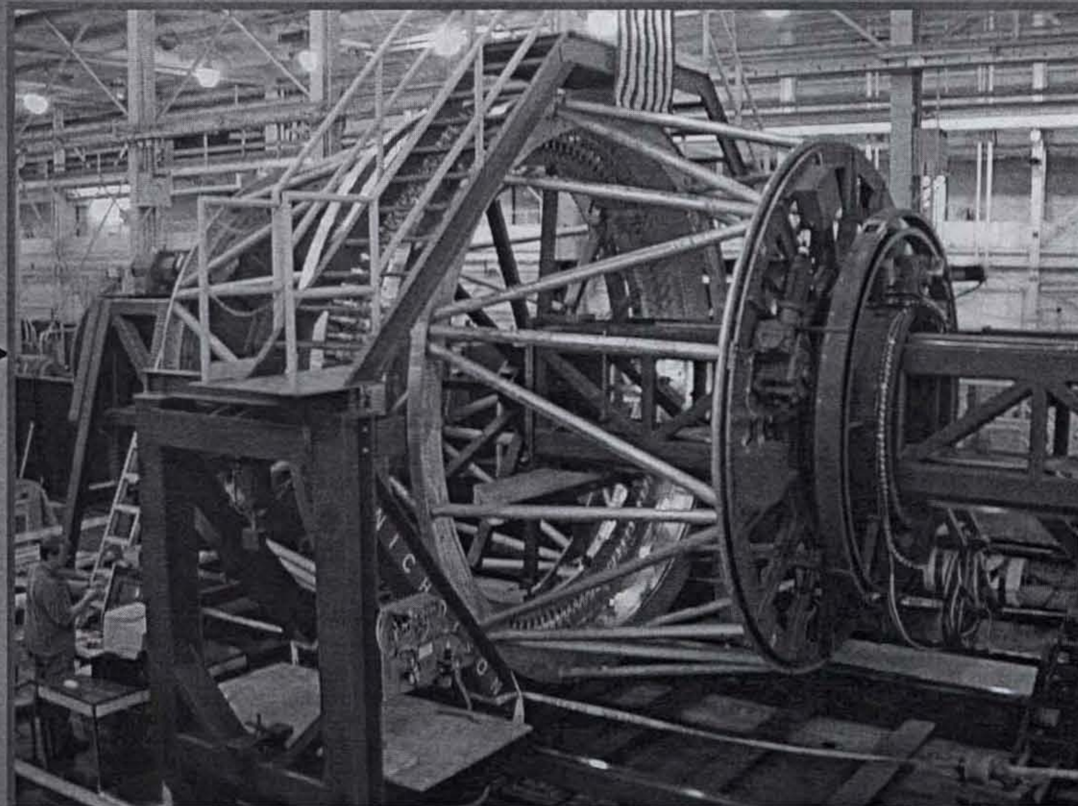


Two Longitudinal FSW Cryotank Barrel Welders
At the Michoud Assembly Facility

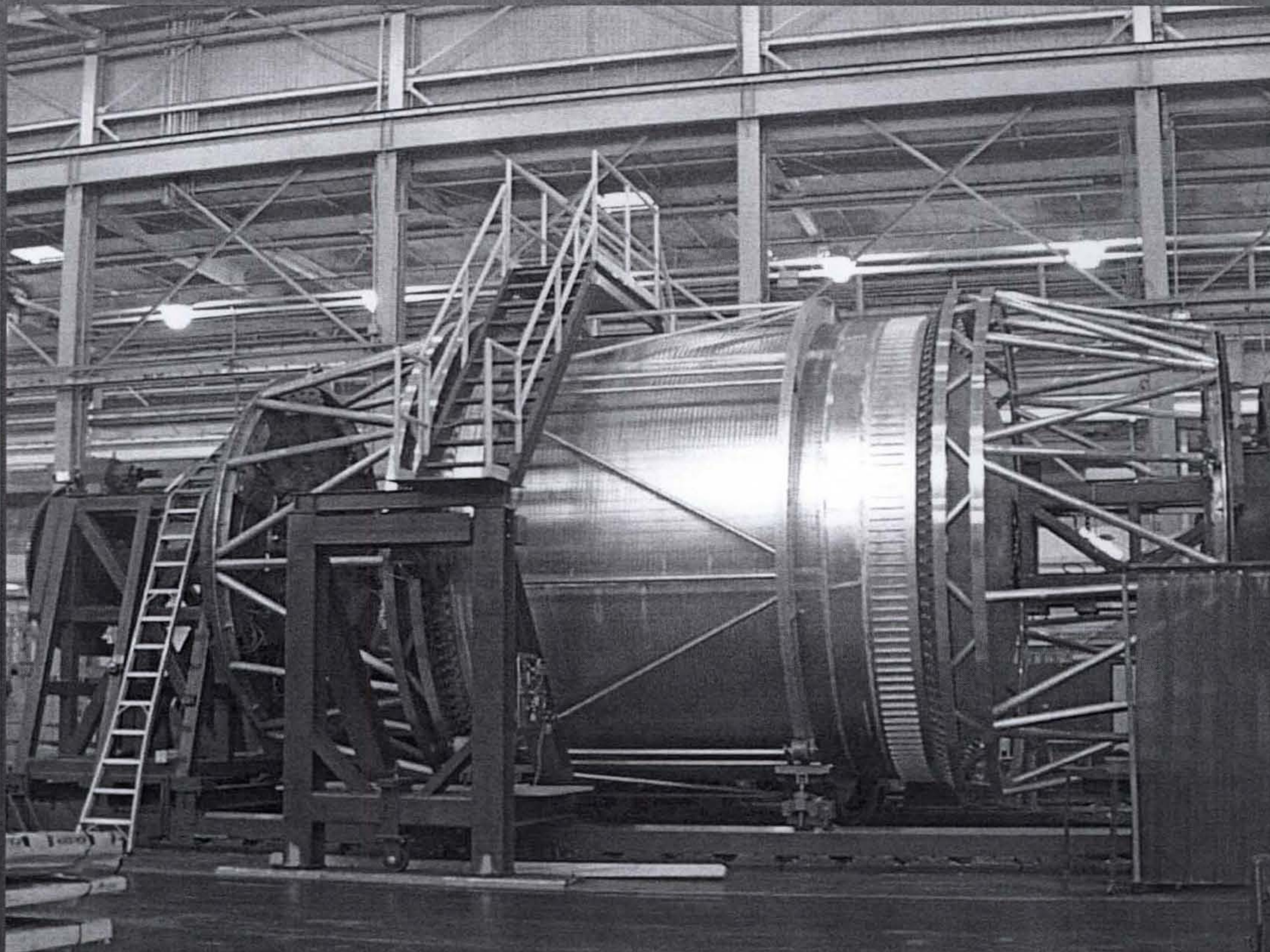
Self-Reacting FSW Development



Panel Welding

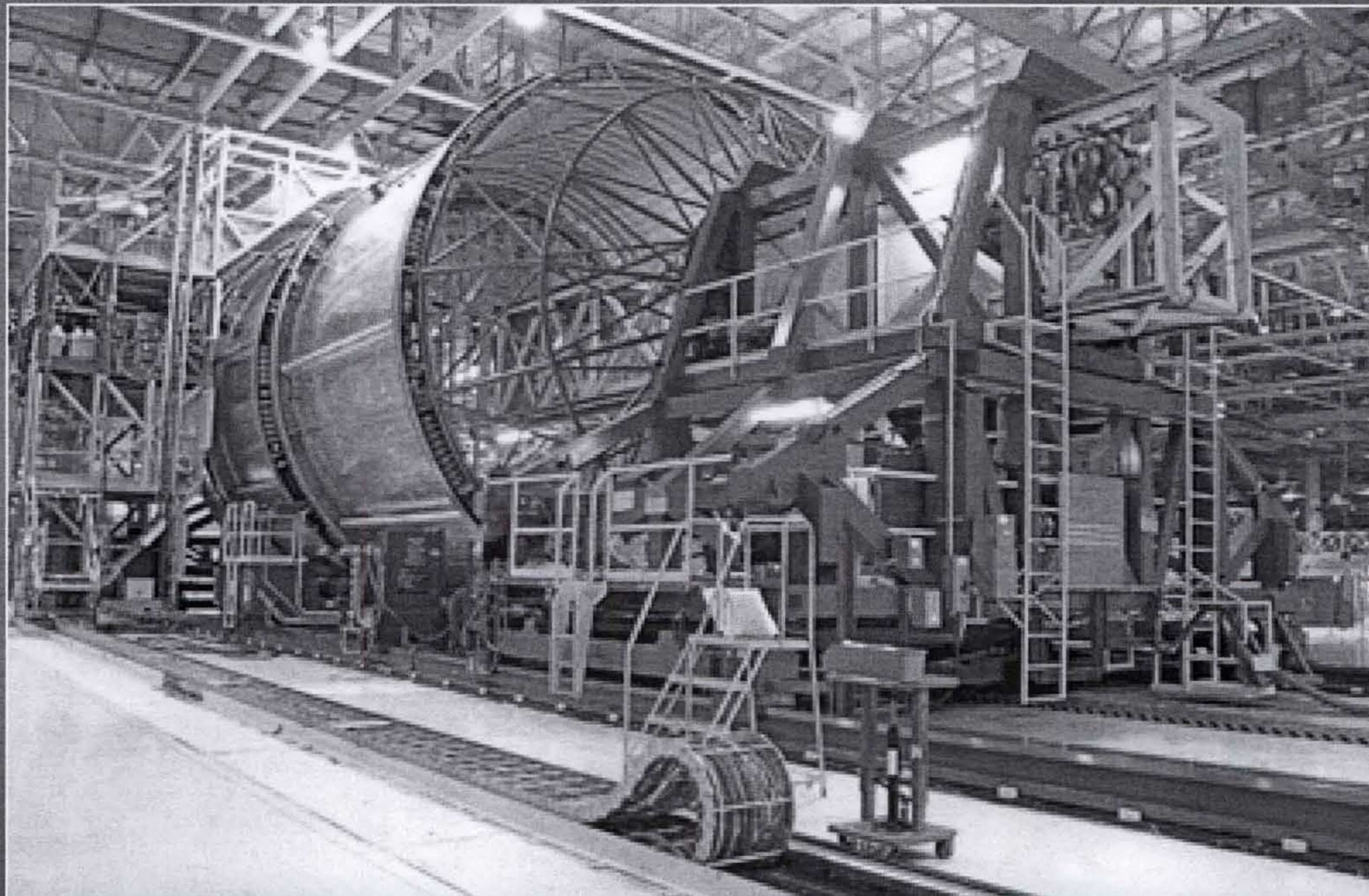


14' Ring Welding Technology Demonstrations at NASA-MSFC Circumferential Weld Tool



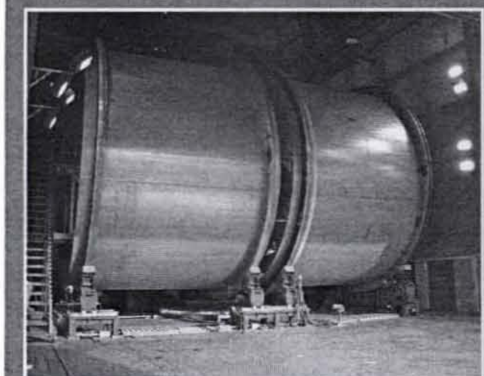
Circumferential Weld Tool

Full Scale Self-Reacting FSW 0.320" Implementation

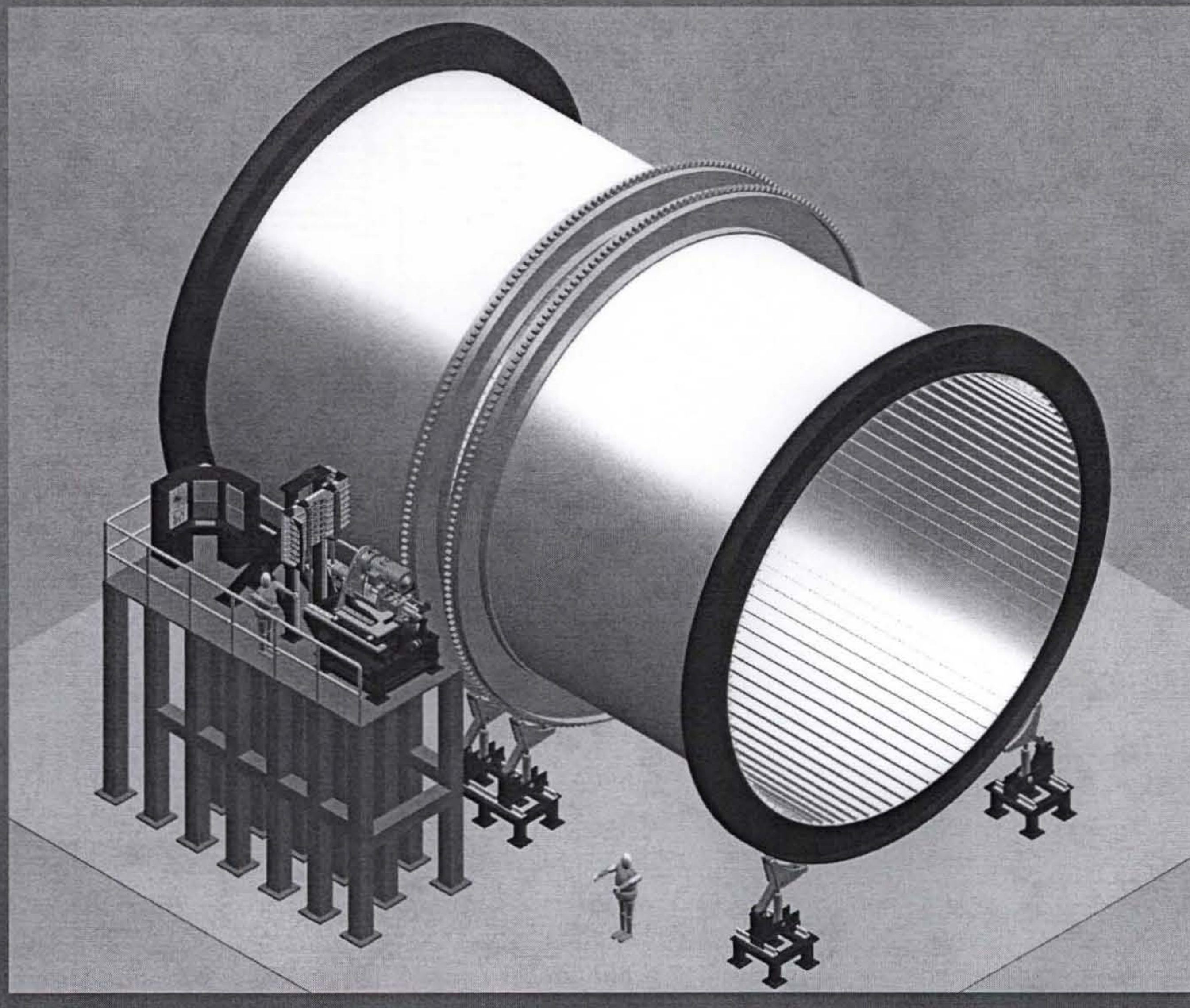


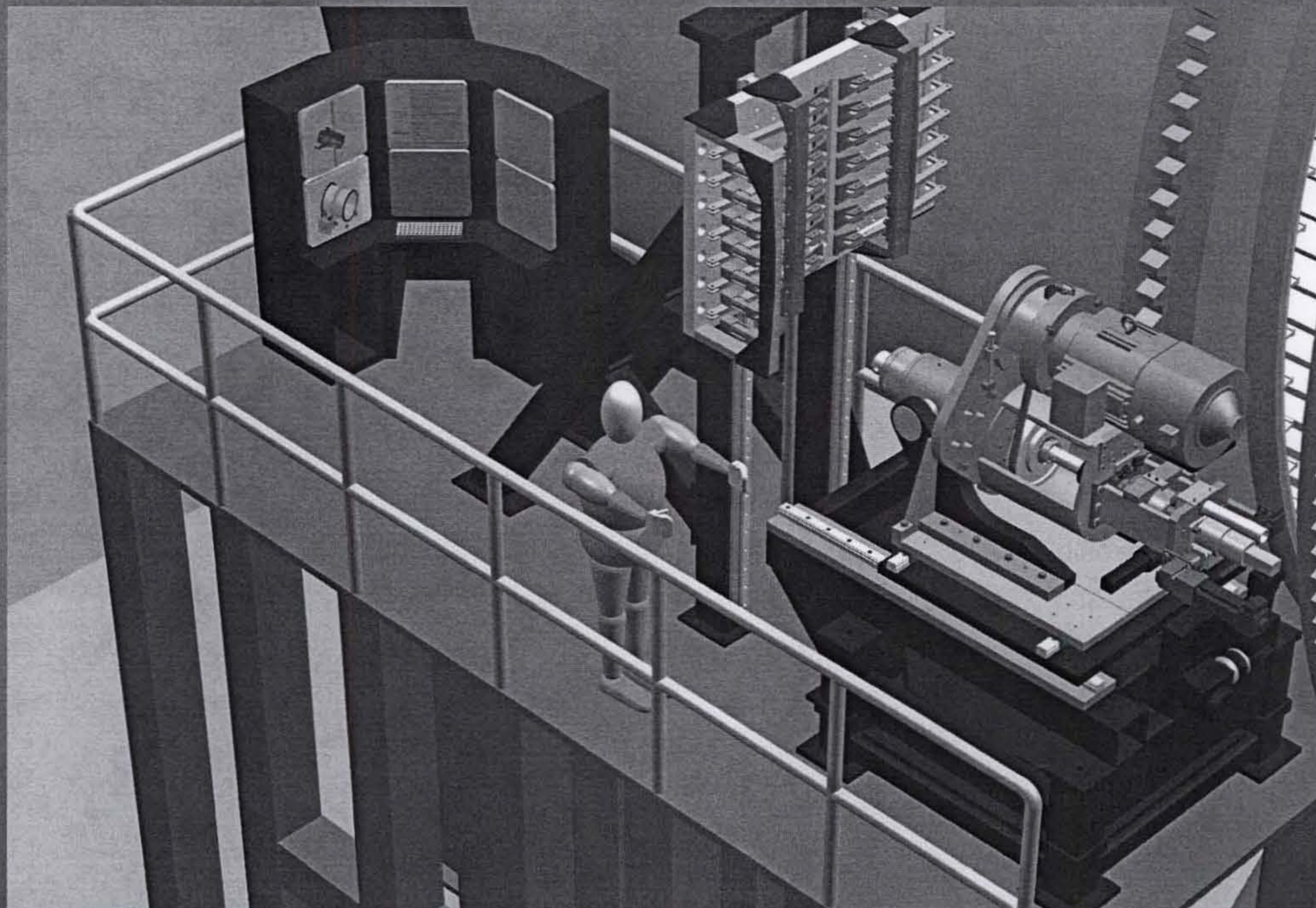
External Tank Tooling for Circumferential SR-FSW

Full Scale Self-Reacting FSW 27.5' diameter Demonstration



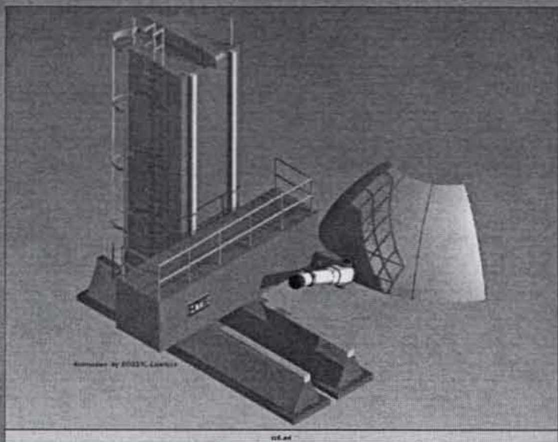
MSFC Building 4707
Horizontal Weld Tool

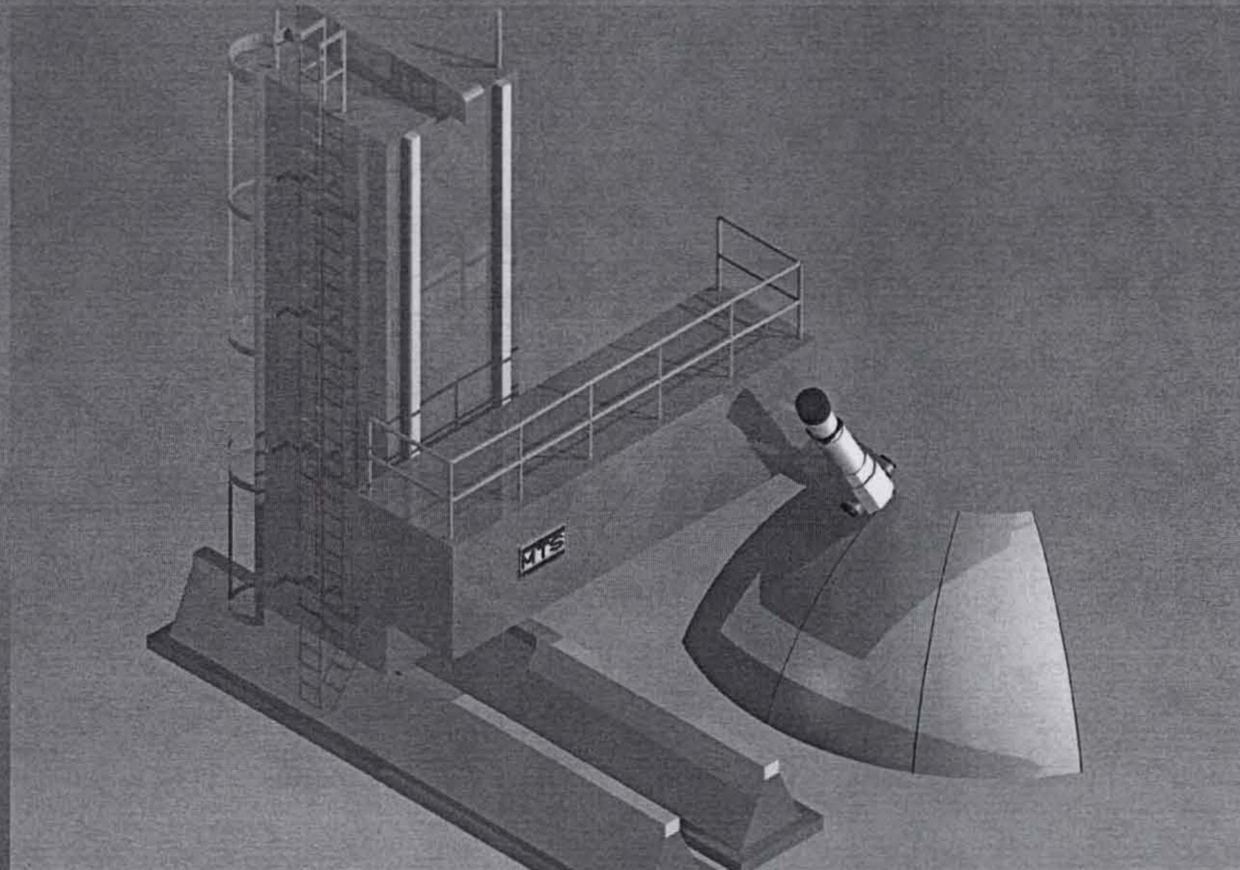




Horizontal Weld Tool Platform

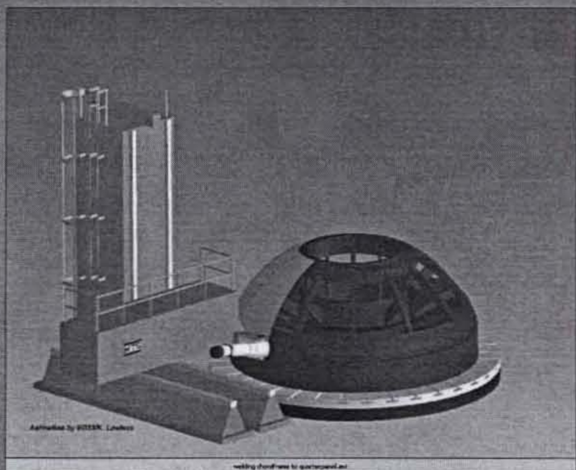
Full Scale Self-Reacting Gore to Gore Demonstration

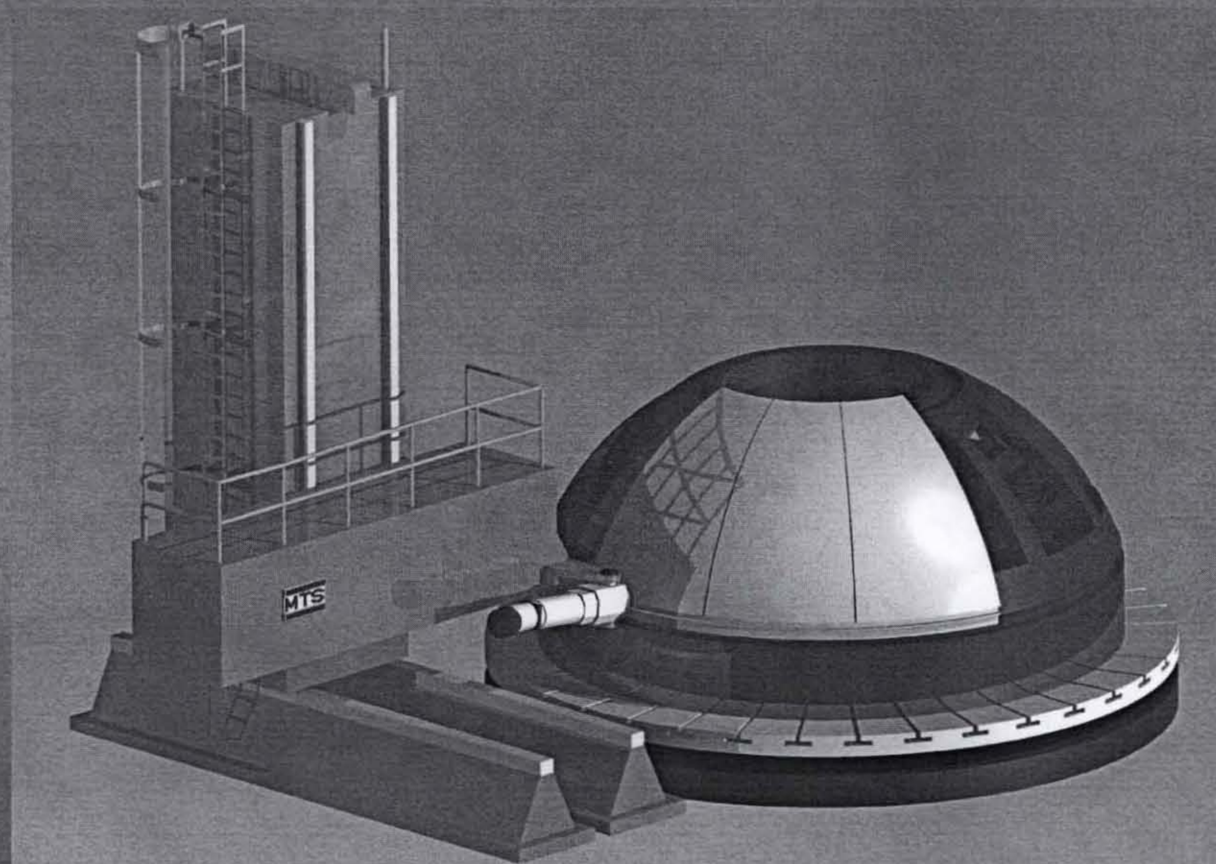




Complex Curvature Friction Stir Welder at MAF

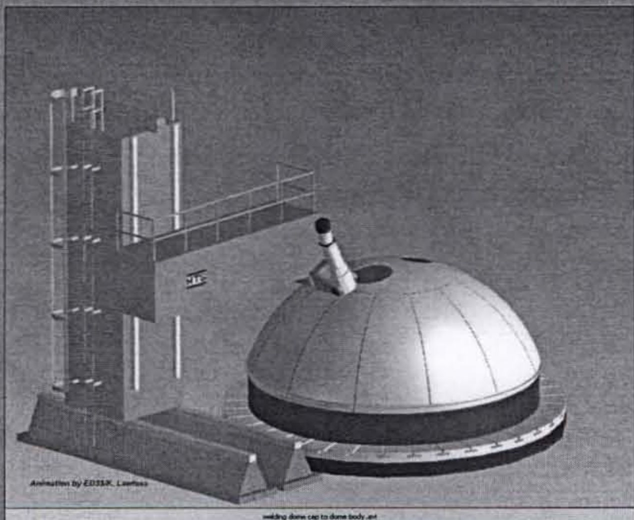
Full Scale Self-Reacting Chord to Gore Demonstration

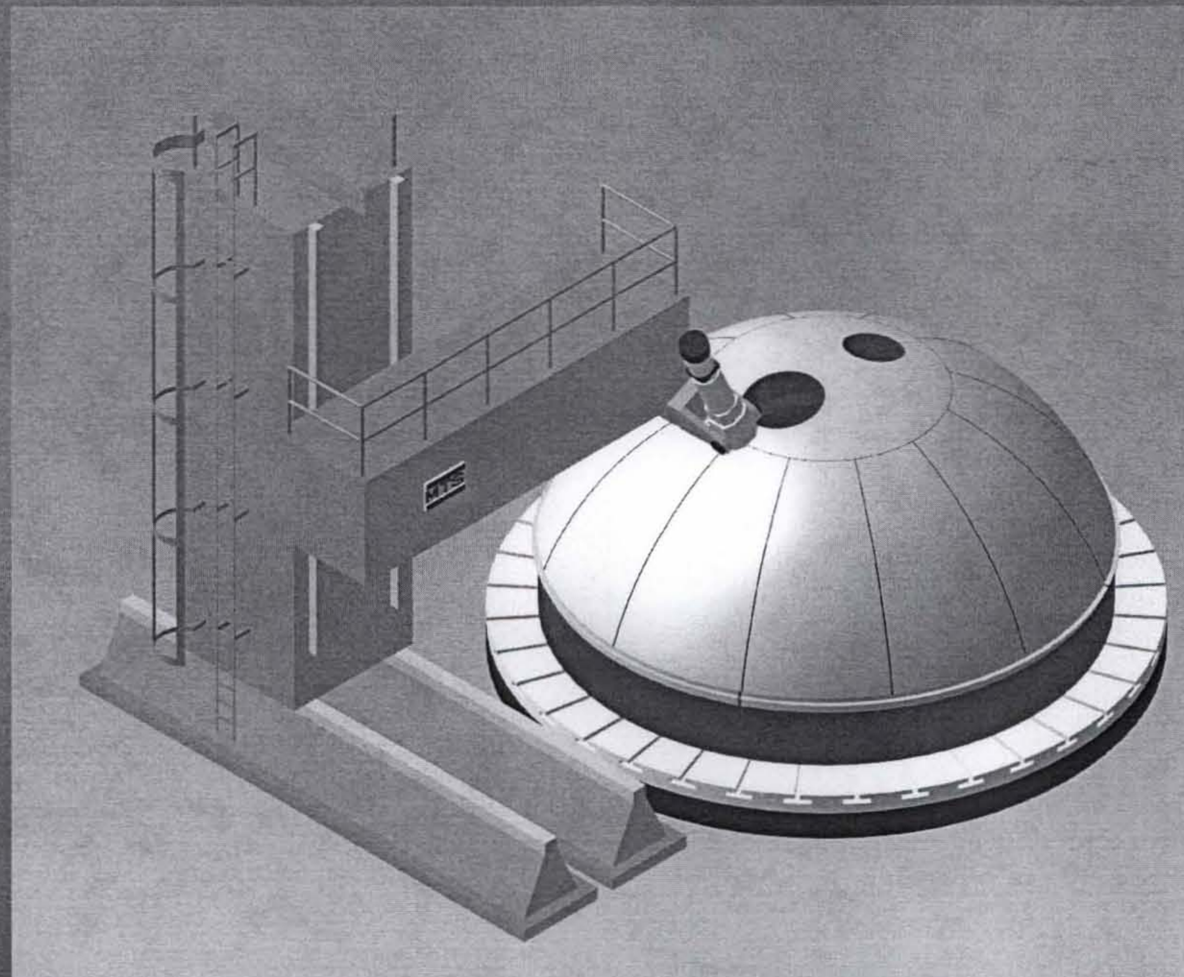




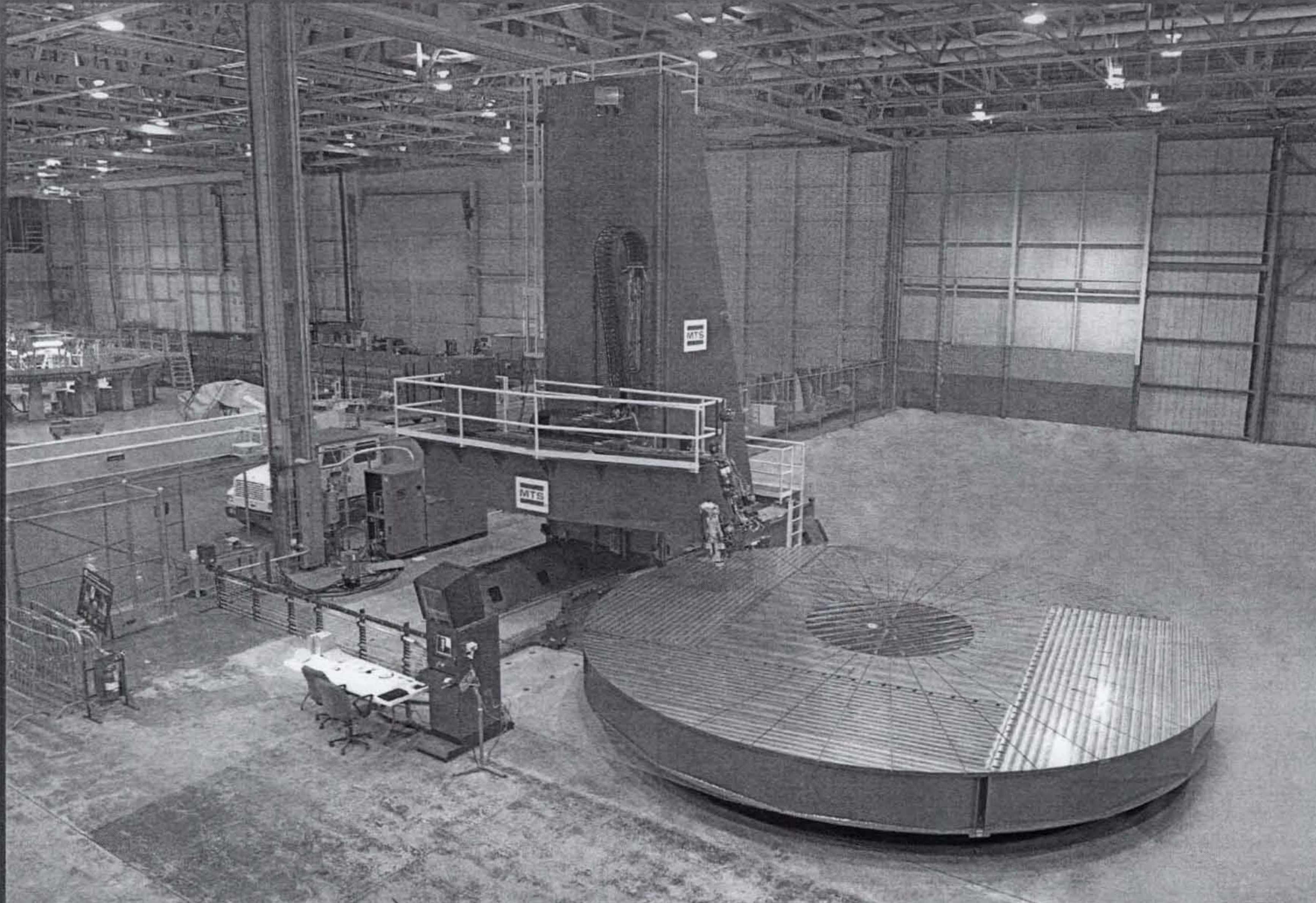
Complex Curvature Friction Stir Welder at MAF

Full Scale Self-Reacting
Dome Cap to Dome Body Demonstration





Complex Curvature Friction Stir Welder at MAF



Complex Curvature Friction Stir Welder at MAF

Thermal Stir Welding (TSW)

- A new solid state welding process similar to friction stir welding (FSW) but with independent stirring, heating and forging function controls.
- Joins similar and dissimilar metals.
- More degrees of freedom for greater process control and optimization.
- Provides mechanical means to produce localized superplastic material in high melting alloys, i.e., titanium.

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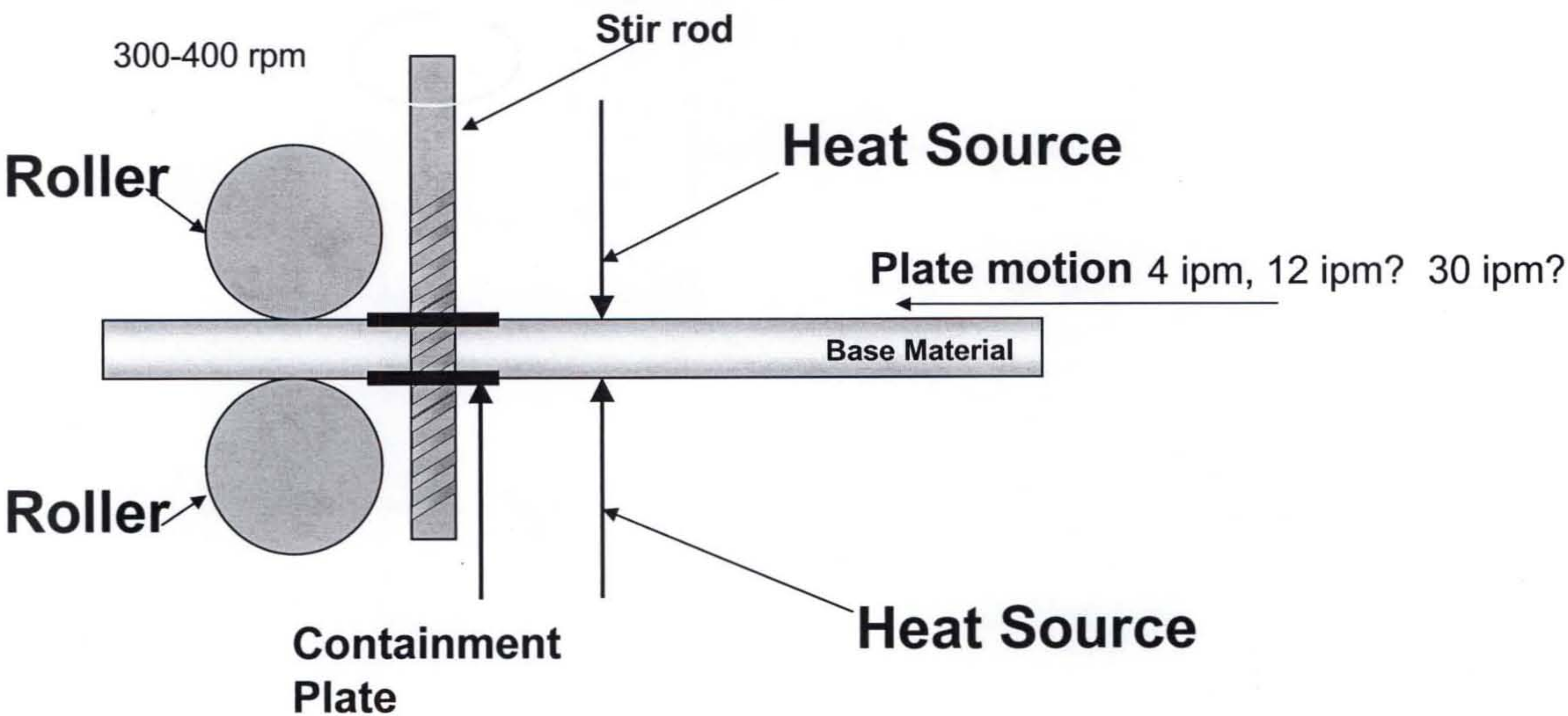
Thermal Stir Welding
Process Description



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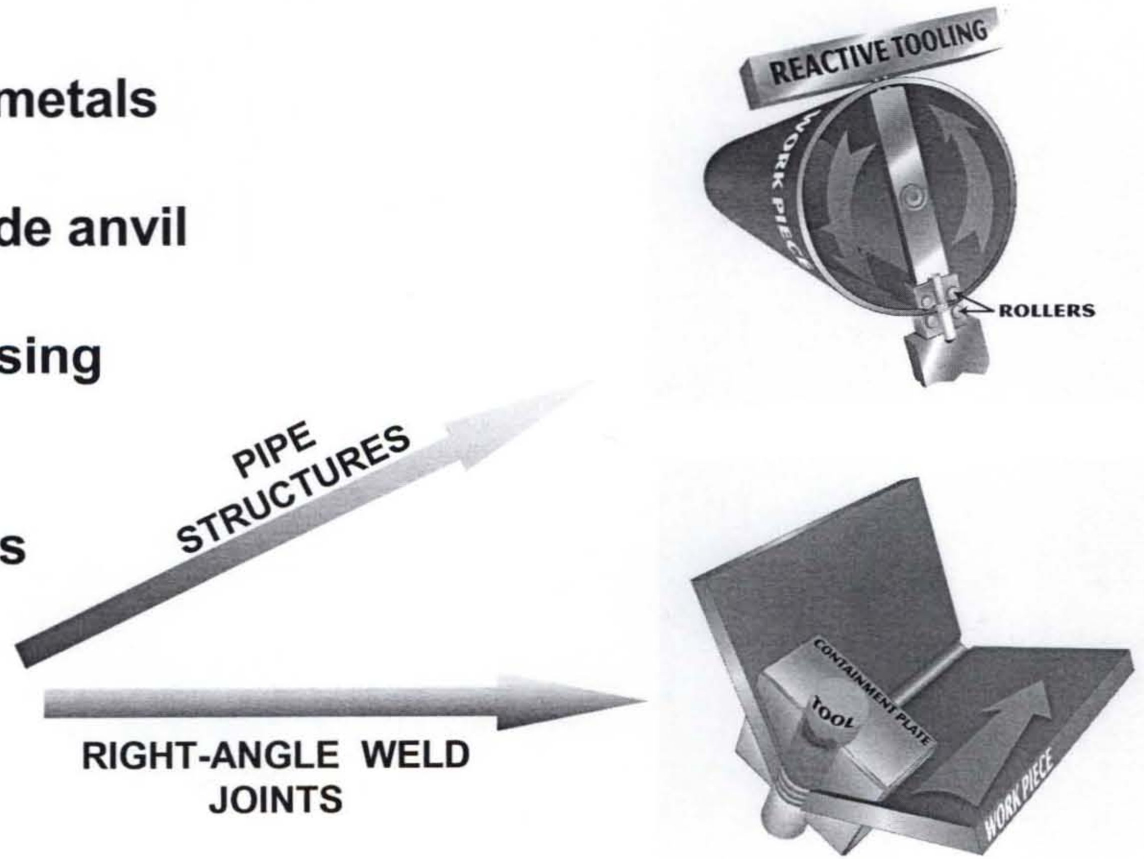
Thermal Stir Welding

- Key-hole close out
- Joining of dissimilar metals
- Elimination of backside anvil
- Optional inert processing environment
- Complex joint designs



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George C. Marshall Space Flight Center
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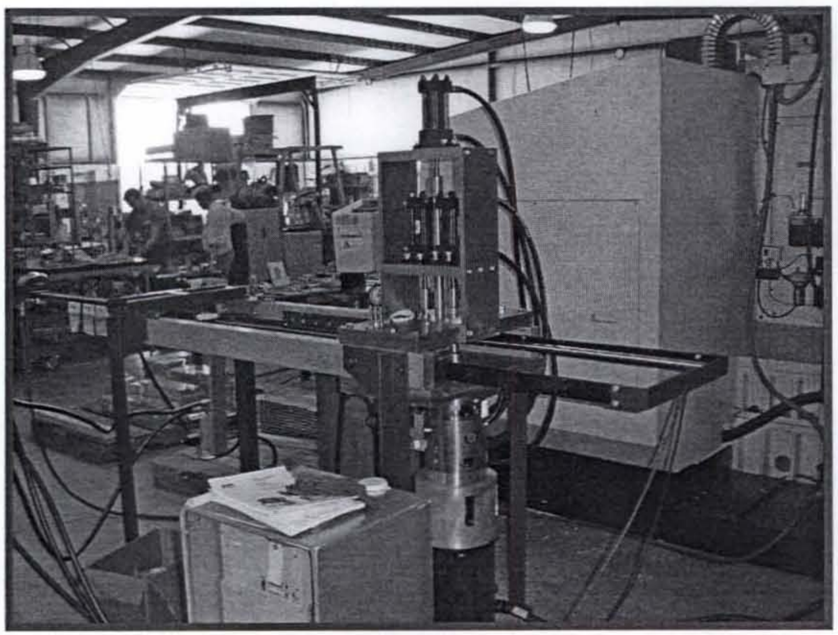
Thermal Stir Welding

Prototype System



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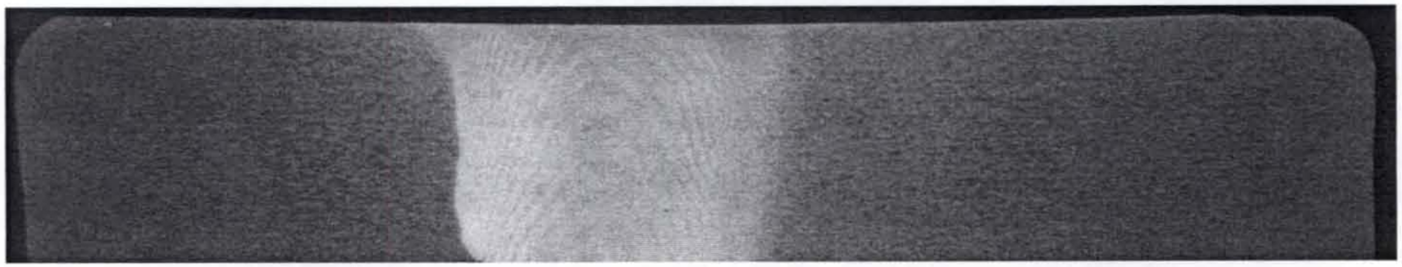
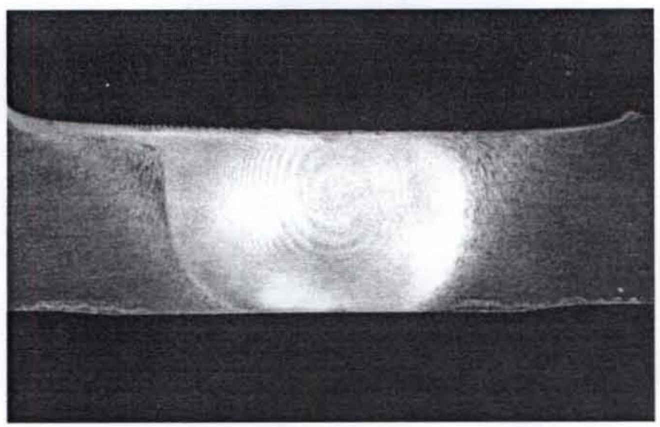
Comparison Between FSW and TSW Microstructure



Macro transverse section of TSW



Macro transverse section of conventional FSW

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